A review of features and characteristics of smart medication adherence products

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ABSTRACT

Background: Smart medication adherence products (smart MAPs) capture and transmit real-time medication intake by using various means of connectivity, allowing for remote monitoring. Numerous such products with different features are available to address medication nonadherence. A comparison of the features of these products is needed for clinical decision-making. Therefore, the objective of this review was to compare smart MAPs available for in-home use.

Methods: We searched grey and published literature and videos to identify smart MAPs. To be considered smart, products required 2 features: connectivity (the ability for collected data to exist outside the physical device) and automaticity (the ability for data to be analyzed or processed automatically). Products were excluded if product descriptions were not available in English, not for in-home use and unable to dispense medications.

Results: Of the 51 products identified, 38 commercially available and 13 prototypes met the definition. Of these, 75% (n = 38) contained alarms, 24% (n = 12) were unit-dose, 63% (n = 32) were multidose, 43% (n = 22) had locking features, 41% (n = 21) were portable and 88% (n = 45) sent notifications to patients. The cost of marketed products, excluding subscriptions, ranged from $10 to $1500 USD. Some products required a monthly (n = 16) or yearly (n = 1) subscription ranging from $10 to $100 USD.

Discussion: There is a growing market of smart MAPs for in-home patient use with variable features. Clinicians can use these features to identify and recommend products according to the specific needs of their patients to address medication adherence. *Can Pharm J (Ott)* 2021;154:312-323.

Introduction

Medication adherence is a major health care challenge worldwide. Studies have shown that in developed countries, more than 50% of patients with chronic illnesses do not take their medications as recommended by their health care provider.[1,2] A systematic review designed to determine the prevalence and nature of medication nonadherence reported that 4% of hospital admissions were caused by medication nonadherence in the studies identified.[3] Furthermore, almost all of the hospital admissions identified were considered preventable.[3] Another study aiming to determine impact of nonadherence on emergency room visits, hospitalization and mortality in patients with heart failure found that a 10% increase in adherence caused an 11% decrease in emergency room department visits,

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- Numerous Internet-based interventions, such as mobile phone applications and web-based systems, are being developed and used to address medication management with the goal of improving medication adherence.
- This study provides a comparison of features of smart medication adherence products that have been designed to address medication management in patients' homes.
- A comparison of the different features of these products will enable informed decision-making among pharmacists when identifying and recommending a smart medication adherence device based on the patient's needs, expectations and capacity.

MISE EN PRATIQUE DES CONNAISSANCES

- De nombreuses interventions basées sur Internet, telles que des applications pour téléphones mobiles et des systèmes basés sur le Internet, ont été élaborées et utilisées pour aborder la gestion des médicaments dans le but d'améliorer l'observance thérapeutique.
- Cette étude fournit une comparaison des caractéristiques des produits intelligents d'observance thérapeutique qui ont été conçus pour la gestion des médicaments dans les domiciles des patients.
- Une comparaison des différentes caractéristiques de ces produits permettra aux pharmaciens de prendre des décisions éclairées lorsqu'ils choisiront un appareil intelligent d'observance thérapeutique et le recommanderont, et cela en fonction des besoins, des attentes et des capacités du patient.

a 6% decrease in hospital admissions and a 9% reduction in overall mortality.[4] Two studies have demonstrated a positive correlation among medication adherence and health-related quality of life in people with chronic illnesses such as diabetes and cardiovascular diseases.[5,6] As such, nonadherence to medications may cause suboptimal management of disease, leading to increased emergency room utilization, hospital readmissions and poor quality of life.[3-6]

Numerous Internet-based interventions, such as mobile phone applications providing disease and medication information, electronic reminders via mobile phone text messages or emails, electronic pill boxes and web-based systems for medication monitoring and education, among others, are being developed and used to address medication management, with the goal of improving medication adherence.[7-9] In a systematic review of Internet-based interventions for medication adherence, researchers found that these interventions have a promising impact on medication adherence in patients undergoing long-term therapies.[10] Medication adherence monitoring can be of great value, especially when it promotes discussion between patients and health care providers for successful treatment outcomes.[9,11]

Electronic medication adherence products have the ability to record and store dosing events, have audiovisual reminders or alarms and provide notifications to patients or caregivers if a dose is not taken by the patient, in addition to dispensing medication doses.[12] In 2017, our research group identified 80 electronic medication adherence products with various features.[13] Twenty-one products were randomly selected to assess their usability, workload and user experience.[14,15] We found significant difference in usability and workload of products among a participant population of older adults, caregivers and health care providers.[14] We also concluded that product features such as the ability to store multiple medications, portability, reminder and alarm functions, among others, can be of significant importance for older adults.[15]

Due to the rapid emergence of the Internet of Things (IoT), "a collection of *smart* devices and wearables that collect and communicate data," the adherence data or feedback is now retrievable instantly in some electronic medication adherence products.[16,17] Products with *smart* capabilities are objects, devices or software platforms that are "embedded with processors, sensors, software or connectivity that allow data to be exchanged between the products and its environment, manufacturer, user and other product systems."[18] Smart medication adherence products (smart MAPs) are novel adherence products that have the ability to track real-time medication intake events remotely, via Bluetooth, Long-Term Evolution (LTE), Wireless Fidelity (Wi-Fi), wired or other means of connectivity, thus making instant real-time electronic adherence feedback a major component of these type of products.[17] In the past few years, the development and use of these products has emerged rapidly, and several reviews have been conducted, identifying both smart and electronic products to address medication adherence.[9,12,17,19]

In 2018, a review of medication adherence technologies done by Aldeer et al.[17] described smart technologies for medication adherence, including smart pill containers, ingestible biosensors, wearable sensors and so on, for medication management. Another review about electronic measurement of medication adherence by Park et al.[9] also reported few such products, including smart blisters, smart electronic medication organizers and smart inhalers, along with electronic adherence products. Checchi et al.[12] conducted a systematic review of electronic medication packaging devices and reported 1 device with real-time wireless monitoring. Although these 3 reviews referred to smart MAPs generally, they did not report or

compare specific features of such products that differentiated them from each other. Another study of electronic monitoring devices exclusively reviewed and described the different features of smart inhalers; however, as extensive as this study was, it did not examine features of devices other than inhalers.[19] Therefore, to the best of our knowledge, there are no studies that have made a detailed comparison of features across different smart MAPs.

This area of research is growing and adapting quickly, and products with smart capabilities are being made available for patient use. As a result, it is imperative for clinicians to become familiar with the common features of smart MAPs and to be able to compare them when considering the use of these or recommending them to their patients. Therefore, the primary objective of this research is to compare the features of smart MAPs, which can inform decisions about which smart MAPs may be best suited for patients based on need, expectation and capacity.

Methods

Study design

This review used a systematic approach to conduct a comprehensive literature search on smart MAPs for in-home patient use. The search was conducted for both published and grey literature to identify as many products as possible, and results were summarized by comparing different features of smart MAPs identified.

Search strategy

A comprehensive search was conducted in 3 databases, including PubMed, EMBASE and Scopus, until November 30, 2019. Keywords and MeSH terms related to "medication adherence," "smart technology" and "dispensing" were used in the search. The Boolean operators AND/OR were used to combine search terms, and where possible, subject headings were combined with keywords in order to build an all-encompassing literature search. See Appendix 1, available online at www.cpjournal.ca, for the detailed search strategy used for all databases. All citations were imported to Mendeley Desktop (version 1.19.4) and duplicates were removed. Title and abstracts of the search results were reviewed by 1 researcher (SF) to identify smart MAPs. A full-text review of potentially relevant citations was completed by a single researcher (SF) to abstract the product information.

To complete the grey literature review, search terms and keywords for Google and YouTube search engines were based on the PubMed MeSH headings. Keywords for the search included medication adherence, smart technology, smart medication dispenser and smart medication devices. One researcher (JI) screened the first 10 pages of Google and first 100 YouTube videos to identify potentially relevant products. Searches were not restricted to the year of publication or geography, but only articles and product information published in English were included. Two researchers (JI and SF) reviewed the final products that met the inclusion criteria from both published and grey literature to include for data abstraction.

Inclusion and exclusion criteria

Smart MAPs were defined as *any device or product that can be used as a medication management aid and that provides real-time medication intake data using connectivity and automaticity*, where *connectivity* is the ability for collected data to exist outside the physical device, and *automaticity* indicates that the data are analyzed or processed automatically or without direct human control.[20]

Products were included if they were for in-home patient use. Both marketed and prototype products were included in this review. Products were excluded if they were stand-alone applications (e.g., mobile applications or software programs), if product descriptions were not available in English or if they were not designed for in-home use.

Data abstraction

Before the process of data abstraction started, 2 researchers developed a list of product features with their definition, based on discussion and previous work with electronic medication adherence products (Table 1). As the data abstraction process continued, the list of product features was updated. Two researchers independently recorded abstracted data from literature, web-based information and YouTube videos using a Microsoft Excel file (version 16.16.14). Any disagreements between researchers were resolved by discussion. The following data were abstracted for each product identified:

a) Product name, status and manufacturer
b) Country where product is available to purchase
c) Type of product
d) Cost of product, including both cost of product and subscription fee, if applicable
e) Product features, including storage capacity, number of compartments, alarm or reminder functions, portability, locking feature and any additional features
f) Product notifications, including type of notification (e.g., telephone call, short messaging service [SMS] notification and/or email), notification recipient (patient, caregiver and/or health care provider)
g) Requirement for a cellular device for optimal product functionality
h) The collection and portrayal of real-time medication intake information

Results

The database search resulted in 307 citations, of which 19 met the inclusion criteria and were included for full-text review of the product information outlined. The initial Google search yielded 1,050,000 results, of which the first 10 webpages or 100

TABLE 1 Product features and their definitions

Product feature	Definition
Product status	
Marketed	The product is available for purchase.
Prototype	The product is still in development.
Product type	
Automated dispenser	Medication dispensers allow access to medications in 1 or fewer human-initiated action. These devices can hold up to a month's worth of medications in small cups, strips or prefilled boxes. Medications are released when the user presses a button.
Dosette or pill boxes	Electronic dosette or pill box with sensors records the time at which the dosette or pill box is opened. Some devices may also record which exact compartment is accessed.
Smart vials or vial caps	Electronic vial or vial cap with sensors on the cap or bottle that record the time at which the vial is opened. Data are transmitted to a cloud portal.
Blister packages or blister package holders	Blister package or blister package holder with an electric component with embedded sensors that track when a blister is perforated. Some devices with sensors hold the blister package while others have electronic ink in the foil of the blister package that sense when the foil has been punctured.
Storage boxes	Electronic medication storage box with sensors that record the time at which the box was accessed and transmit this information to a cloud portal.
Inhaler or inhaler devices	Electronic inhaler that digitally records use. Can be the inhaler itself or an electronic device that attaches to an existing inhaler.[9]
Injectors	Electronic injector that digitally records use.
Cost	
Upfront cost	The monetary cost of buying the product or service. This value did not include subscription costs.
Monthly subscription	The monetary cost of monthly subscription use of a product or service. This value includes cost that is mandatory for some products and optional for others.[21]
Yearly subscription	The monetary cost of yearly subscription to use a product or service. This value includes cost that is mandatory for some products and optional for others.[21]
Storage capacity	
Unit-dose	The ability to store only 1 dose of 1 medication.
Multidose	The ability to store multiple doses of 1 or more medications.
Locking feature	A feature that restricts access to medications without the use of a specific procedure, such as using a key or entering a Personal Identification Number or passcode, or that incorporates facial recognition software.
Portability	Any device that can be easily taken on-the-go and fits inside a purse or small bag.
Alarms	Audio or visual alarms produced by or sent from the product to the user.
Notifications	Alerts including text messages, phone calls or emails sent by the device to a user, caregiver or health care provider.
Mobile phone requirements	Any product that requires a user to download an app or own a mobile phone in order to set up and use the product. Nonuse of a mobile phone limits the use of features of the product or completely limits use of the product.
Connectivity	The manner by which a device is connected or interconnected (e.g., Wi-Fi, Bluetooth, near-field communication) in order to allow for real-time monitoring.
Additional features	Features not defined in the list above.

results were reviewed. The YouTube search did not provide an initial number of search results yielded; therefore, the first 100 results were reviewed. Of the results reviewed from both Google and YouTube, 59 were included for full-page review of the product information. Supplemental information regarding YouTube videos was searched using Google if not enough information was provided in the video. Similarly, if not enough information was provided in the Google webpage, supplemental information was sought through YouTube, product websites or other third-party websites. See Appendix 2 (available online at www.cpjournal.ca) for the PRISMA flow diagram.

In total, 78 products were identified through database, Google and YouTube searches, of which 14 were duplicates. After the duplicates were removed, 64 products were screened for eligibility, leaving 51 products in the final review (Table 2).

Of these products, 38 (74.5%) were commercially available and 13 (25.5%) were prototypes. Of the commercially available products, 9 (23.7%) were available globally, 26 (68.4%) in North America, 2 (5.3%) in Europe and 1 (2.6%) was available globally except in North America. The key characteristics of the smart MAPs identified are described in Table 3. For a list of smart MAPs and their respective features, please see Appendices 3 to 5 (available online at www.cpjournal.ca).

Product types

The literature review identified 5 types of oral and 2 types of nonoral smart medication adherence products. The oral products included automated dispensers ($n = 20$), dosette or pill boxes ($n = 9$), smart vials or vial caps ($n = 7$), blister packages or blister package holders ($n = 5$) and storage boxes ($n = 4$). The non-oral smart MAPs included inhaler or inhaler devices ($n = 5$) and injectable devices ($n = 1$).

Product features

Storage capacity. Approximately two-thirds of the products assessed had the capacity to store multiple doses of 1 or more medications and, as such, were classified as having a multidose storage capacity. These multidose devices had a wide range of compartments allowing for the administration of multiple medications at multiple times during the day. For instance, the Philips Medication Dispenser can hold 60 cups of medications for up to 6 doses per day, whereas MedaCube can hold up to 16 medications and dispense for up to 90 days.[44,47] These multidose smart devices provided different means of holding the medications; some (e.g., Wisepill RT 2000) were storage boxes that allowed the user to store any kind of medications they had, and others (e.g., MedaCube) required that contents of vials be transferred to bins in the device, where the device would then pick out the number of medications needed from the bin at the appropriate time.[31,44] Some devices required medications to be loaded individually (e.g., Pria or Pillo), and others required blister cards (e.g., Emma or RxPense), pill packs (e.g., spencer or Karie) or cups (e.g., Philips) to be inserted into the device.[27,41,47,50,54,57,69]

Twenty-three percent ($n = 12$) of the smart MAPs identified were unit-dose devices. These products were smart vials or vial caps, injectors or inhalers. A total of 13.7% ($n = 7$) of smart MAPs identified did not report the storage capacity of the products.

Locking feature. Of the smart MAPs identified, 43.1% ($n = 22$) contained a locking feature that allowed for access to medication at the prescribed time, as set up initially by the user, caregiver or health care provider. Some devices such as Hero have an optional locking feature that uses a passcode to restrict who has access to the medications.[37] Pria and Pillo use a similar system; however, rather than a passcode, facial recognition or Personal Identification Number (PIN) code is used to restrict medication access.[50,54] RxPense contains advanced voice biometrics, allowing for authentication of medication administration through the user's voice, by asking the user to utter a simple phrase displayed on the screen.[57] Some products like Evendos have locked compartments for missed medication doses and restrict who can fill the device by only allowing those with a key to access its interior in order to remove missed doses and fill the device. This key access is given to a health care provider.[30]

Portability. Approximately 40% of products identified were portable. Some portable products included Wisepill RT2000, which weighs 130 g and is 30 × 60 × 130 mm in size, and Popit Sense, which weighs 12 g and is 31 × 45 × 12 mm.[31,53]

Alarms and notifications

Alarms. An alarm or reminder function was found in 74.5% ($n = 38$) of the products identified. These alarms ranged from visual alarms such as flashing lights, text displayed through the device, audible sounds, vibration prompts or a combination of these. Alarms were used to remind users that it was time to take their medications and, in some instances, would give instructions as to which medication or compartment to take, how to access the medication and any additional reminders that a user may need when taking the medication, such as to take with food or take with a glass of water. For instance, RxPense provides a series of visual, audible and vibration alerts to the user through the device, which can be adjusted based on the user's preference.[57] MAYA and JON, by MedMinder, contain audio and visual alerts to indicate which compartment should be opened and at which time.[40,43] The visual alert highlights the correct compartment, and the audio alert can be programmed to a custom audio message.[40,43]

Notifications. Notifications were provided by the smart MAPs to users, their caregivers and health care providers. Forty-five products (88%) provided notifications to users, and 26 (51.0%) provided notifications to caregivers and/or health care providers. Of the products that provided notifications to users,

TABLE 2 Smart medication adherence products included in review ($N = 51$)

Smart medication adherence product	Manufacturer
Airduo digihaler[22]	Teva Pharmaceutical
DoPill[23]	Domedic
Dyn-e-pill system[24]	NR
Electronic Medication Dispenser[25]	NR
Elliegrid[26]	Elliegrid
Emma[27,28]	INRange Systems, Inc.
e-pill MedSmart Plus[29]	Cadex Watch
Evondos[30]	Evondos
evriMED1000[31]	Wisepll Technologies
Findair[32]	Krakow Tech
GlowCap[33,34]	Vitality, Inc./NantHealth
GMS Bluetooth Automatic Pill Dispenser[35]	GMS
Hailie[36]	AstraZeneca
Hero[37]	Hero
iLidRx[38]	iRXReminder LLC
inPen[39]	Companion Medical
JON[40]	MedMinder
Karie[41]	AceAge, Inc.
Livi[42]	PharmRight Corporation
MAYA[43]	MedMinder
MedaCube[44]	PharmAdv
Medicube[45]	NR
MedReady MR-357FL[46]	MedReady
Philips Medication Dispenser[47]	Philips
Pill Connect[48]	Euclid
Pillgo[49]	QuaLife
Pillo[50]	Pillo Health
Pillsy[51]	Pillsy, Inc.
PillTracker[52]	PillTracker
Popit Sense[53]	Popit
Pria[54]	Black+Decker
ProAir digihaler[55]	Teva Pharmaceutical
Propeller Sensor[56]	Propeller Health

(continued)

TABLE 2 (continued)

Smart medication adherence product	Manufacturer
RxPense[57]	Medipense
Sensemedic blister box[58]	Evalan
Sensemedic pill dispenser[58]	Evalan
Sensemedic pill bottle[58]	Evalan
SimpleMed+ Medication Dispenser[59]	Vacia
Smart blister pack[60]	NR
Smart blister pack[61]	NR
Smart bottle[62]	AdhereTech
Smart Drug dispenser[63]	Balda Health care
Smart medication dispenser[64]	NR
Smart pill box[65]	NR
Smart Pill Box Medicine Management System[66]	Bluestar Seniortech
Smart pillbox[67]	Jeyun Medical Co
SmartMedReminder system[68]	Concordance Health Solutions
spencer[69]	Catalyst Health
TabSafe[70]	TabSafe Medical Services, Inc.
Time4Med[71]	Adherence Innovations
Wisepill RT2000[31,72]	Wisepll Technologies

NR = Not reported.

these notifications were commonly SMS notifications or phone call reminders following a missed medication dosage. Some products provided notifications through a mobile application. Of the products that provided notifications to caregivers and/or health care providers, these notifications were commonly SMS notifications, emails or phone calls. In some cases, these notifications were also provided through a web-based or mobile-based recording platform, primarily to clinicians and/or health care providers. MAYA and JON reminded the patient through a phone call if they missed a dose and would notify family members or caregivers by phone, email or text message if there was no response following the initial patient phone call.[40,43] The prototype Smart Drug Dispenser by Balda Health Care provides mobile notifications to patients through their mobile application.[63] Clinicians are notified via SMS or email if a patient misses a dosage.[63]

Mobile phone requirement

Of the smart MAPs identified, 41.2% of products required a mobile phone to allow the product to function to its full capacity. In many cases, a cell phone was required to download the product's associated application, to set up and fill the product, to demonstrate the user's adherence rate and/or to track the user's adherence.

Smart medication adherence product connectivity and real-time monitoring

Smart MAPs were connected by a variety of means, including cellular network (e.g., 2G/3G/4G and LTE, via Subscriber Identification Module [SIM] card), Wi-Fi/ Ethernet, near-field communication (NFC), radiofrequency identification (RFID) or Bluetooth to provide real-time medication monitoring to a user's caregiver or health care provider. Real-time medication monitoring was provided to health care providers and caregivers through a mobile application or web-based portal hosted through the cloud.

Cost

The upfront cost of marketed smart MAPs ranged from $10 to $1500 USD. Some products ($n = 7$) required a subscription fee along with this upfront cost. Of the products requiring a subscription fee, 42.71% ($n = 16$) charged a monthly fee ranging

TABLE 3 Product features ($N = 51$)

Product feature		% (*n*)
Product status	Commercially available	74.5 (38)
	Prototype	25.5 (13)
Product type	Automated dispenser	39.2 (20)
	Dosette/pill box	17.6 (9)
	Vial/vial cap	13.7 (7)
	Blister pack	9.8 (5)
	Inhaler device	9.8 (5)
	Storage box	7.8 (4)
	Injectable	2.0 (1)
Type of subscription for commercially available products	Monthly subscription	44.7 (17)
	Yearly subscription	2.6 (1)
	Not reported	7.9 (3)
	No subscription	42.1 (16)
Upfront cost in US dollars of commercially available products*	<$50	11.5 (3)
	$50-$99	15.4 (4)
	$100-$500	23.0 (6)
	>$500	15.4 (4)
	Not reported	26.9 (7)
	No charge	7.7 (2)
Monthly and yearly subscription cost in US dollars of commercially available products	<$50	50.0 (9)
	$50-$99	33.3 (6)
	>$100	5.6 (1)
	Not reported	16.7 (3)
Storage capacity of device	Unit-dose	23.5 (12)
	Multidose	62.7 (32)
	Not reported	13.7 (7)
Locking feature	Yes	43.1 (22)
	No	54.9 (28)
	Not reported	2.0 (1)
Portability	Yes	41.2 (21)
	No	41.2 (21)
	Not reported	17.6 (9)

(continued)

TABLE 3 (continued)

Product feature		% (*n*)
Alarm	Yes	74.5 (38)
	No	25.4 (13)
Notification to patient	Yes	88.2 (45)
	Visual alarms	71.1 (32)
	Audio alarms	64.4 (29)
	SMS messages	26.7 (12)
	Telephone call	11.1 (5)
	Email	8.9 (4)
	Vibrating alarms	6.7 (3)
	Not specified	4.4 (2)
	No	11.8 (6)
Notification to caregiver	Yes	47.1 (24)
	SMS messages	70.8 (17)
	Email	45.8 (11)
	Telephone call	29.2 (7)
	Not specified	4.2 (1)
	No	51.0 (26)
	Not reported	2.0 (1)
Mobile phone requirement	Yes	41.2 (21)
	No	58.9 (30)

SMS, short messaging service.
*Some products had an upfront cost along with a subscription fee.

from $10 to $100 USD, and 2.6% ($n = 1$) charged a yearly fee of $99 USD (approximately $8.25 per month). Two products had an optional subscription fee. EllieGrid had an optional fee to obtain report data for approximately $4 per month.[26] Wisepill had an optional fee of $0.50 per month for on-call support.[31] In some products, such as Hailie, ProAir digihaler and Airduo digihaler and inPen, the cost is dependent on copay as per a patient's insurance plan or the dispensing pharmacy.[22,36,39,55] In this review, we have reported the cost for these devices based on the projected price without copay. Two products, Propeller Sensor and Smart bottle from AdhereTech, were available for patients free of charge.[56,62]

Additional features

Of the smart MAPs identified, many contained additional features that we did not summarize above. For instance, some devices such as RxPense, spencer and Evondos have voice and videoconferencing directly from the device, allowing for virtual visual visits.[30,57,69] Evondos also has the ability for caregivers and/or health care providers to send messages to the device user through the device screen to allow for the collection of information, such as "How do you feel after receiving your bloodwork today?"[30] Some devices, such as Livi, Philips, Karie and Pillgo, also allow for an early dose function.[41,42,47,49] This feature allows users to request access to their medications prior to their scheduled dose.

Discussion

This overview summarizes a comprehensive range of features of smart MAPs for medication management. The most prevalent features of these products that were compared in this review include type of product, country or region of

availability, cost and product-specific features such as storage capacity, audiovisual alarms, locking ability, portability and feedback via notification process.

We found that smart MAPs differ in their physical characteristics as well as the features they offer. A number of studies have begun to investigate the usability and acceptability of smart MAPs, along with other electronic medication products being released in the market.[14,27,73,74] The need for different features of these products may depend on particular needs, expectations and capacities of the user. For instance, the number of compartments to hold medications will drive the choice of product based on the number of times a user is prescribed to take a medication. Convenience in the number of times a product will need to be refilled will also affect which product is chosen. Therefore, number of compartments in the device is a useful feature to consider when choosing a product for patients, especially those who are on multiple regular drug therapies managing multiple medications (e.g., individuals with chronic diseases or older adults with multiple comorbidities). Similarly, locking features may be required for patients with memory or cognitive impairments in order to prevent accidental double dosing due to forgetfulness, or for overdosing in individuals prescribed narcotics, or to prevent young children from accessing their parents' or grandparents' medications.

Our previous research regarding the user experience of MAPs has shown that portability is a feature that users consider when choosing a product for their medication management needs.[15] Similar results were shown by a qualitative study regarding patients' views about electronic adherence devices. This study reported that patients preferred products that were lightweight and smaller in size due to the fact that they were more convenient to carry around.[75] As such, portability is an important feature to consider when recommending or purchasing a product for individuals who are living independently or who have active lifestyles.

Reminders or alarm functions are another important feature of the smart MAPs reviewed. A systematic review on drug reminder packaging has indicated that using devices that have alarms or reminder functions can improve adherence.[12] Smart products with reminder functions that allow audio and/or visual cueing of dosage events may be useful in changing the behaviour associated with medication intake, especially in patients with nonadherence due to forgetfulness. Given increasing risk of declining vision, hearing and sensation as individuals age, options for the type of reminders, whether visual, auditory and vibratory, are important factors for consideration when choosing a product to use.

Smart MAPs have the ability to record, analyze and transmit medication intake data to a web-based portal in real time. When it is time to take the medications or when users do not access the medication as scheduled via smart products, these products have the ability to analyze that information and send messages to patients. Thus, these products not only act as a reminder to address forgetfulness or unintentional nonadherence but also allow health care providers to remotely access patients' adherence data in a timely manner. Conventional methods of measuring adherence such as pill counts, patient self-reports and pharmacy refill records are often used in practice; however, these methods lack reliability.[60,67] Although real-time medication adherence data cannot guarantee that the patient has actually ingested, injected, inhaled or applied the medication, these data can allow clinicians to act in a timely manner, initiate a conversation about the link between adherence and optimal management of diseases and avoid unnecessary dose increases or additional therapy.[19] The availability of real-time adherence data can help clinicians not only in clinical decision-making but also as a tool to motivate patients to modify their medication intake behaviour or assess why nonadherence is occurring.[9] As such, this data can be valuable in providing integrated care to complex patients. Studies have reported that monitoring real-time medication intake behaviour provides an opportunity for health care providers to achieve positive adherence outcomes in nonadherent patients.[76] Future studies should examine patient preference of these products, product usability, impact on adherence and use in routine clinical care.

Strengths and limitations

To the best of our knowledge, this is the first review that summarizes features of smart medication adherence products. The searches were limited to products available in English, the first 10 pages of Google and the first 100 YouTube videos. Therefore, this may not be representative of the global market of smart MAPs, and some available products may have been missed. This review only focuses on describing features of the products through the information available online. As such, these products were not purchased or tested by our research team. There may be additional features not described in the product description available online that may affect the results of this review. In addition, not all products included in this study were tested with patient populations to enable us to report the impact on patient adherence through product use. Furthermore, where adherence has been measured, there is significant variability in the definition of adherence utilized in the studies, as well as the tools used to measure adherence. Therefore, a review of adherence for these products would require another systematic review of the studies conducted. However, this review simulates the features by which a clinician could review the products prior to making a recommendation. Neither the usability of these products nor the impact on adherence or health outcomes through the use of these products was analyzed; however, this was not the objective of this study.

Conclusion

Smart MAPs are being developed and are available to purchase for patient use. However, due to the variability of their features,

it can be challenging for clinicians to search for an appropriate product. Clinicians should be able to identify the products on the basis of their features and match them with their patients' needs. Our study may serve as a resource to inform clinicians about the key features that are currently offered by smart medication adherence products. Clinicians can then use this knowledge to recommend products that best match patient limitations and expectations. ■

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