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Co-design of a digital solution for total hip and knee arthroplasty journey: A case study

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Abstract

End-users' involvement is crucial to develop human-centered solutions; patient acceptance and endorsement by clinicians will be achieved when the features of digital solutions align with their needs and expectations.

The aim of the study was to develop the overall concept of digital solution to increase transparency, foster patient adherence, and improve patient-provider communication across the entire total hip and knee arthroplasty journey from admission to discharge, and beyond.

Two-stage iterative co-design process was used. Systematic literature reviews and qualitative interviews were conducted to understand the problem. In addition, co-creation sessions were used develop the solution for a reference implementation.

As a result, a total of 19 technical and functional requirements were identified. In addition, ten additional functional requirements were identified for future design. The results demonstrate the overall concept of a digital solution for the reference implementation. The uniqueness of the solution lies in the vision of wider integrated systems, which could offer a clinical platform for clinicians to provide patient-focused care remotely, while monitoring patients' progress closely.

Keywords: digital care pathways, telemedicine, tertiary healthcare, secondary care

Introduction

Hospitals are enhancing the effectiveness of their services, not only in terms of costs but also regarding health outcomes and patient experience [1]. At the same time, the patient's role is changing from receiver of care to active participant and co-producer of healthcare services. Recently, several platforms have been developed to support patients' self-management capabilities to improve health outcomes [2-4] and reduce costs [5,6] in patients with osteoarthritis. There is, however, a complete lack of targeted and tailored solutions covering the entire total hip arthoplasty (THA) and total knee arthoplasty (TKA) journey from admission to discharge, and beyond [7].

End-users' involvement is crucial to develop human-centered solutions [8]; the adoption by patients and endorsement by clinicians will be achieved when the features of digital solutions align with their needs and expectations [9]. According to the ISO 9241−210 standard [10], *"Human-centered design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques".*

Instead of theory-based approaches, human-centered design was used to optimize collaboration among stakeholders to improve patient experience (e.g., satisfaction, expectations, patient-reported outcomes) and integrate digital solutions into clinical practice in an achievable way [11-13]. It includes interactive and iterative phases to understand and specify the context of use, specify user requirements, design a solution, and evaluate the design against requirements [10].

This study was part of a co-innovation project that co-created and evaluated the impact of intelligent patient-centric digital solutions in orthopaedic and pediatric surgery care journeys from medical, patient, and business perspectives. The term *"digital"* reflects the fact that all the aspects of care that are possible to digitize are delivered in digital format. By *"patient journey"* we refer to the whole patient path from the first encounter to the control visit, including all periods spent at home, in hospital, or in any other care facility. Thus, in our context digital solution can be defined as *"application of information and communication technologies to identification and resolution of issues related to the experiences of patients through a defined episode of care".*

Material and methods

Aim

The aim of the study was to develop the overall concept of digital solution to increase transparency, foster patient adherence to the fast-track protocol (enhanced recovery program) protocol, and improve patient-provider communication across the entire THA/TKA journey from admission (e.g., preoperative preparations) to discharge (e.g., postoperative actions), and beyond (e.g., rehabilitation). The research question was: *"What are the technical and functional requirements for digital patient journey solution in THA/TKA journey"?*

Design

A two-stage iterative co-design process using human-centered approaches was used to understand the problem and develop the solution (Figure 1).

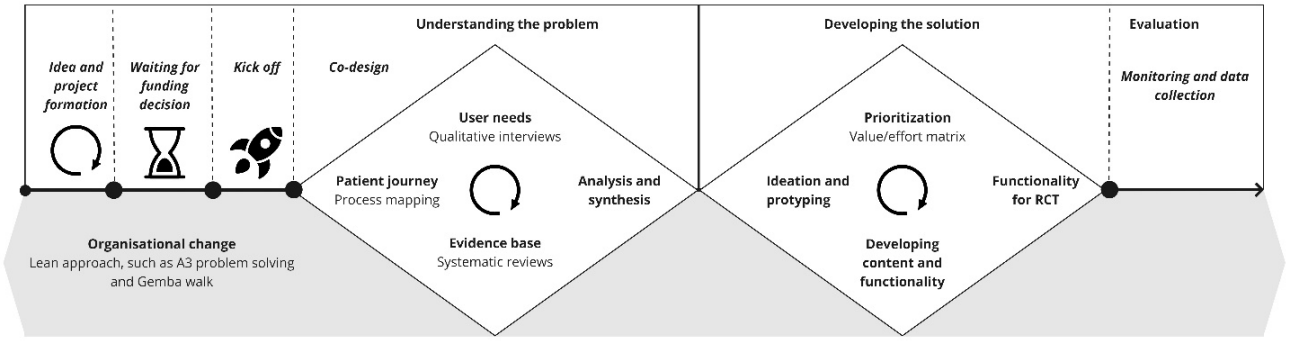

Figure 1. Overview of the human centric-co-design process.

Understand the problem (Phase 1)

Qualitative interviews

Qualitative interviews were conducted in 2018 to describe end-user's requirements for digital solutions in the THA/TKA journey. Semi-structured in-person interviews were conducted among 20 patients undergoing or having undergone elective THA/TKA [14]. In addition, ten nurses, six doctors, and four physiotherapists were interviewed [15,16]. Patients were recruited during a preoperative surgical visit, post-operative care, and control visit. The healthcare professionals were recruited from the same joint replacement center. The interview questions were framed by a topic guide that constituted the four main parts of the patient journey in the selected context. The interviews lasted between 20–58 min. All data were transcribed immediately by a transcription service provider.

Systematic literature reviews

Systematic literature reviews [17,18] were conducted in January 2019 and February 2020 to describe functional requirements that increase transparency, foster patient adherence, and improve patient-provider communication pre-, intra- and post-surgery. Studies were identified from four multidisciplinary databases (Medline Ovid, Scopus, Ebsco Databases, Web of Science). The study selection process was carried out by two researchers independently. Studies were included if they met the predefined inclusion criteria that were based on the population (patients with orthopaedic disorders), the intervention (e.g., digital solutions), comparators (standard care), and the type of outcome (e.g., patient outcomes and resource utilization).

Analysis and synthesis

The data from systematic literature reviews and transcribed interviews were analyzed and synthetized by inductive content analysis [19] and the whole consortium was familiarized with the results. The findings provided new perspectives on how to increase transparency (e.g., timeline, navigator with map, peer-support), foster patient adherence to the fast-track protocol (e.g., self-scheduling, to-do list, self-monitoring, daily reminders, digital/push-up notifications, educational messages, diaries), and improve interactive patient-provider communication (e.g., text chat with a possibility to send photos, video calls, audio-visual instructions, telephone follow-up, digital referral) in THA/TKA journey. In addition, the findings contributed new perspectives on how to visualize results and evaluate the impact of developed solution during a

reference implementation (e.g., patient-reported outcome and experience measures) [20].

Develop the solution (Phase 2)

Co-creation sessions (No: 3) were held among hospital representatives (one orthopaedic surgeon, one registered nurse), researchers, and five companies at the key moments during the project to discuss and reflect on the collected data and to generate new ideas and make decisions regarding the future development directions. A typical session took 2-3 hours and involved 10-20 stakeholders. Human-centered approaches (e.g., co-creation sessions, workshops) were used to integrate patients' experiences, clinicians' expertise, and the results of systematic literature reviews into interactive and iterative phases to develop the overall concept of digital solution for a reference implementation.

Developing content and functionality

The educational content of the digital solution was developed based on the existing paper-based instructions. Because patients found the counseling materials to be insufficient and old-fashioned [14], the educational content was updated and integrated into the digital solution based on the improvement ideas identified in the semi-structured interviews [14-16]. Prior to reference implementation [20], the three content experts agreed that the health information provided was appropriate and the feasibility of solution was tested among three THA/TKA patients. Based on the feedback, the minor changes were made to the user interface (e.g., background color, icons).

Ideation and prototyping

A process-mapping [21] was used to in line with the A3 problem solving and Gemba walk. During a workshop, the pain points were identified by the hospital representatives, and the companies described their existing technologies, development ideas, and how they solutions could be integrated into the THA/TKA journey.

During the co-design, companies built mock-ups of the overall concept of the digital solution, planned how their existing technologies would work together, and designed the functionality of the digital solution. Together with researchers, companies identified the timeline (e.g., predefined tasks, scheduled clinical visits, appointments, and any other check-points during the journey, push notifications), self-monitoring functions, and clinician dashboard (e.g., user interface, push notifications).

Prioritization

During the workshop, technical and functional requirements for the digital solution were prioritized using a value/effort matrix (also known as an action priority matrix) to plan an effective roadmap. The value/effort matrix included four quadrants: 1) minimal-effort and low-impact; 2) maximum-effort and low-impact; 3) high-impact and minimum-effort; and 4) high-impact and maximum-effort to optimize limited time and resources. Prioritization was conducted simultaneously in three separate groups: by the hospital representatives, by the research organizations, and by the companies. The results were compared, and a shared understanding was established. Because the technology readiness of all ideated requirements did not reach the required technology readiness in a given time, less prioritized technical and functional requirements were categorized as future functionalities.

Ethical considerations

The study was reviewed by the local ethics committee (Decision No: 83/2018). Writen informed consent was obtained from patients and healthcare

providers prior to inclusion in the study to ensure that the participation was voluntary (Declaration of Helsinki, 2013). All researchers processing the raw interview data signed a data processing agreement. A steering committee, which included representatives of all consortium partners, was formed to monitor overall progress of the project.

Results

The overall concept of a digital solution

The digital solution is a collection of several digital services and applications (See Figure 2). From the users' point of view, the digital solution appears as a single user interface showcasing different solutions and encompassing a multitude of services from different service providers.

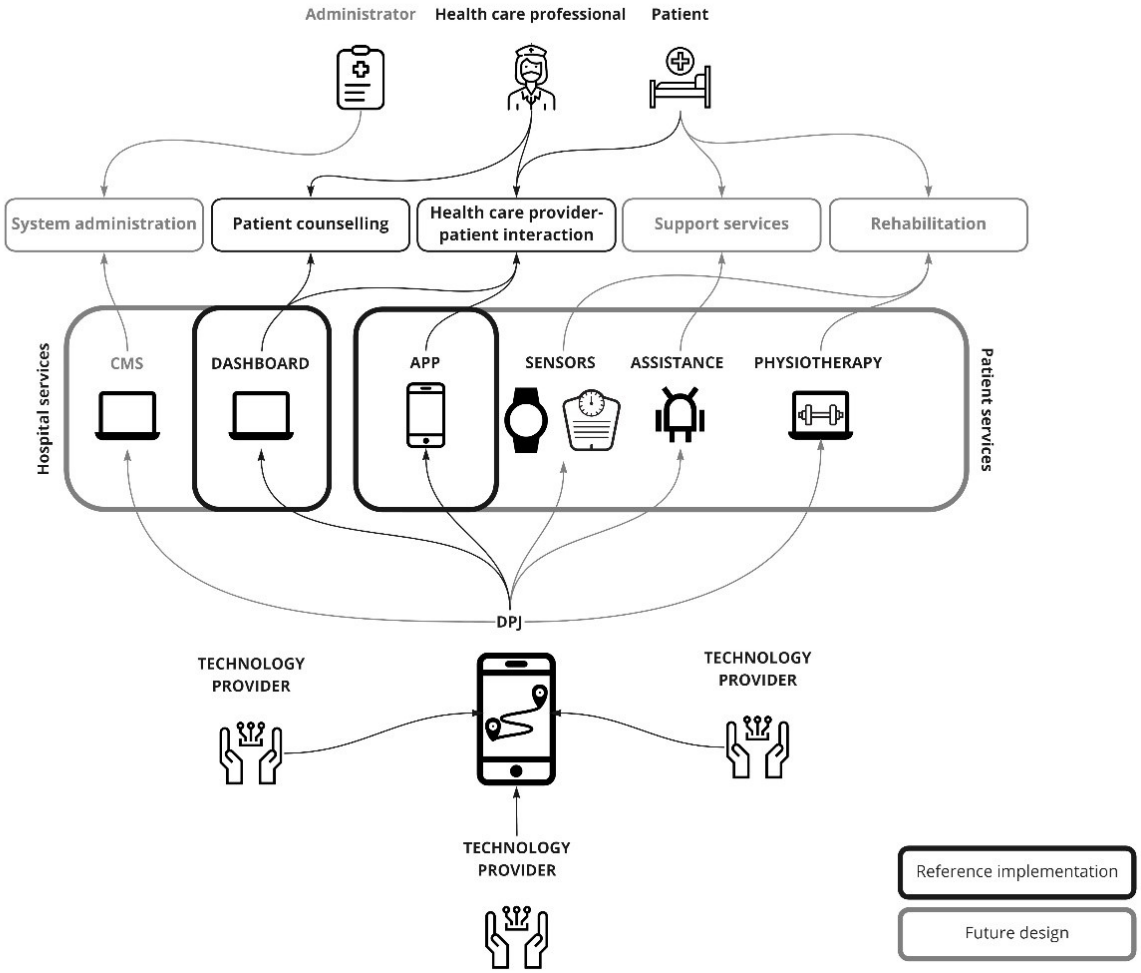

Figure 2. The overall concept of the digital patient journey (DPJ) solution, which consists of a native app for patients and a clinician dashboard for health care providers. CMS, Content Management System.

The reference implementation with a subset of services from the overall digital solution was based on an integration of Near Real solution (www.near-real.com, Near Real Connect, version 1.13 for Android, version 1.10 for iOS) and the engagement platform by Buddy Healthcare (www.buddy-healthcare.com, BuddyCare, version 2.24.0) [20]. The digital solution can be downloaded from Google Play or App Store using a personal activation code.

Patients interact with clinicians through a mobile device. The native app was developed to support THA/TKA patients' self-management capabilities from admission to discharge, and beyond, at any time and in any location. The main feature of the app is a visual timeline representation, which aims to increase the transparency of the THA/TKA journey. The landing page provides access to multimedia messaging to improve patient-provider communication, well-structured multimedia content to improve the access to reliable health information, and scheduled reminders and push notifications to foster patient adherence to the fast-track protocol.

The clinicians use the solution for patient counselling and interacting with the patients through a clinician dashboard which they can use from their computers. In addition, they are able to monitor patient status in real time, e.g., adherence to fast-track protocol, identify potential problem situations, and intervene if patients require additional support.

Technical requirements

The reference solution included the following eight technical requirements (Table 1).

Table 1. Technical requirements for digital solution across the entire THA/TKA journey.

Requirement	Definition	Source
Mobile use	The patient should be able to use the digital solution with a mobile device.	Co-creation sessions
Connectivity	The mobile device serves as a gateway between the patient and the digital patient journey solution. The mobile device connects to sensors providing data to the applications via wireless connection (e.g., Bluetooth). Connection with the hospital is established via local mobile network connection. The hospital users access the digital solution via the hospital internal network.	Co-creation sessions
Security and privacy	The digital solution deals with personal data, which poses strict requirements for data protection. Only authorized persons should have access to the data and access is provided only through appropriate user identification protocols. Secure health data approved cloud services should be used. All data should be encrypted in transfer between the framework services and in resting state.	Co-creation sessions
Data quality	The digital solution should have mechanisms to ensure data quality, such as, accuracy, correctness, consistency, completeness, timeliness and validity. The data should be stored appropriately so that adequate and reliable information is provided to the patient. External data modifications should not be permitted.	Co-creation sessions
Scalability	The framework should support integration of new services along the patient journey allowing for more comprehensive and personalized patient care. It should be possible to extend the digital solution from specialized medical care in primary care, and also by combining the two.	Interviews, co-creation sessions
Offline use	The digital solution should support offline use. This allows patients to access information even during periods of connectivity problems.	Co-creation sessions
Logging in	The digital solution should allow access for the user without the need to log in every time. The native app is installed in the patient's personal smartphone or tablet, and thus enables secure access to the content and data.	Co-creation sessions
Regulatory compliance	The digital solution needs to be Health Insurance Portability and Accountability Act and EU General Data Protection Regulation compliant.	Co-creation sessions

Functional requirements

The reference solution included the following eleven functional requirements (Table 2).

Table 2. Functional requirements for digital solution across the entire THA/TKA journey.

Requirement	Definition	Source
Timeline	The digital solution should provide a visual timeline, which should represent the predefined tasks with pre- and postoperative instructions in chronological order to increase transparency. In addition, it should show the scheduled clinical visits, appointments, and any other check-points during the journey. Combined colors should indicate the status of the tasks; orange tasks should be conducted, pink are urgent tasks, green ones are successfully completed, and blue tasks are upcoming.	Interviews, systematic literature reviews, co-creation sessions
Summary	As a motivational feature, the digital solution should provide a summary of tasks (to-do list) with manual confirmation to foster patient adherence to the fast-track protocol.	Interviews, co-creation sessions
Reminders and notifications	The digital solution should provide automatic reminders and push notifications about the upcoming events and tasks (e.g., fasting, medication) to foster patient adherence to the fast-track protocol.	Interviews, systematic literature reviews, co-creation sessions
Multimedia content	The digital solution should include scheduled education sessions (e.g., rehabilitation) with multimedia content (i.e., text, images, audio, and video). The topics should include all instructions regarding preoperative preparation and post-discharge care in a digital format.	Interviews, systematic literature reviews, co-creation sessions
Self-monitoring	The digital solution should enable self-monitoring (e.g., steps, pain) to foster patient adherence to the fast-track protocol. For example, a mobile embedded accelerometer should provide means for activity tracking or for counting steps.	Interviews, systematic literature reviews, co-creation sessions
Forms	The digital solution should provide a reporting tool for pain (symptom logging) on a Visual Analogue Scale (VAS) and both generic and disease-specific patient-reported outcomes (PROs) in a digital format. In addition, it should provide tools for self-monitoring. Different measures can be displayed for clinicians within the hospital to provide customized information and triage patients	Interviews, systematic literature reviews, co-creation sessions
Messaging	The digital solution should enable real-time or near-real-time chat to improve patient-provider communication. Patients should be able to send their queries and pictures at their convenience through the chat box to the clinicians.	Interviews, systematic literature reviews, co-creation sessions
Video calls	The digital solution should enable video calls to improve patient-provider communication.	Interviews, systematic literature reviews, co-creation sessions
Dashboard	The clinicians should manage patient information and their journeys via a web-based dashboard. They should, for example, a) create personal activation codes, and add b) new users, c) individualized tasks, as well as d) prescheduled events (e.g., video appointments) into the timeline. The dashboard should allow the clinicians to monitor whether the patient has signed the relevant information packages related to the operation as read and whether the patient has filled in all the relevant questionnaires. The clinicians should see the messages and images the patient has sent via the application and react accordingly. Possible sensor data and measurements which the patient has completed should also be viewed via a dashboard.	Co-creation sessions
Search	The search functionality should enable the user to search for any information along the timeline.	Co-creation sessions
Menu	The menu should provide a reporting tool for pain, step-monitoring functionality, message and video communication functionality, hospital information, information videos and pictures, and user settings.	Co-creation sessions

Functional requirements for future design

Ten additional functional requirements were identified for future design (Table 3).

Table 3. Functional requirements for future solution.

Requirement	Definition	Source
Profiling	The digital solution should include screening questionnaires with instructions related to indications for surgery and eligibility criteria, reflecting the need to personalize the pathway to surgery and to provide lifestyle counselling pre- and post-surgery. It could also increase the transparency of decision-making for the patient.	Interviews, co-creation sessions
Early pre-operative assessment	The digital solution should shift the timing of pre-operative assessment to much earlier in the pathway in case the patient is in need of lifestyle counselling. This could support patients' engagement to lifestyle change as part of their pre-surgery care. Early engagement should occur at the time of initial diagnosis of osteoarthritis. In addition, screening questionnaires could be used to allocate patients to low-, medium-, and high-risk pathways.	Interviews
Lifestyle counselling	The digital solution should include comorbidity management and life-style counselling for risk groups in order to modify patient risk profiles and lifestyle factors (e.g., smoking, alcohol consumption, physical activity).	Interviews
Rehabilitation	The digital solution should include specialized support for rehabilitation. This could include a gamified rehabilitation solution utilizing artificial intelligence for motion sensing, as an example.	Interviews, systematic literature reviews
Self-monitoring	The digital solution should enable more comprehensive self-monitoring (e.g., vital signs, adherence to rehabilitation exercises, evaluation of physical performance). In addition, it should include personalized exercise programs with individual targets and visualization (e.g., diary and progress reports), discharge criteria with daily targets in a digital format, and support for pain management and weaning afterwards.	Interviews, systematic literature reviews, co-creation sessions
Online scheduling	The digital solution should enable an online scheduling (e.g., clinical appointments, surgery), which should be integrated into resource planning and the hospital scheduling system. In addition, it should reschedule timeline representation automatically. The patient should be able to monitor referral status and estimated appointment time with one week's accuracy. Patients should also receive an early digital notice of an appointment with preparation instructions.	Interviews, co-creation sessions
Chat	The digital solution should enable live messaging with the clinicians i.e. chat. It could be based on an intelligent chatbot functionality that could provide answers to the most frequently asked questions. Furthermore, this functionality should utilize data to provide more relevant answers even to more complex questions.	Interviews, systematic literature reviews, co-creation sessions
Peer support	The digital solution should provide peer support for patients. This could include patient stories in multimedia format to support and motivate for conducting preparation tasks pre-surgery and rehabilitation activities post-surgery.	Interviews, co-creation sessions
Support for navigation	The digital solution should provide support for navigation, both indoors and outdoors with a map and audio-visual instructions.	Interviews, co-creation sessions
Patient medication list	The digital solution should incorporate personalized medication information, notifications, and dosage with integration to the electronic health record.	Interviews, co-creation sessions

In the future, hospital services should include a Content Management System for administrators or clinicians designing the content for the journey. For the reference implementation, this information was provided manually for the technology provider and then included in the digital solution. Furthermore, the patient services should include support services, such as robotics providing assistance, and rehabilitation services utilizing modern sensor technologies for motion sensing.

Discussion

Human-centered approaches were used to integrate patients' experiences, clinicians' expertise, and the results of literature reviews into interactive and iterative phases. Technical (mobile use, connectivity, security and privacy, data quality, scalability, offline use, logging in, regulatory compliance) and functional (timeline, summary, reminders and notifications, multimedia content, self-monitoring, forms, messaging, video calls, dashboard, search, menu) requirements were prioritized to develop the overall concept of a digital solution to increase transparency, foster patient adherence to the fast-track protocol, and improve patient-provider communication across the entire THA/TKA journey. In addition, ten additional functional requirements were identified for future design.

According to our findings [7,8], the digital solution differs from other similar solutions in transparency; the whole care process is visible to the patient from the beginning. Furthermore, the digital solution implements a horizontal process, in which the patient proceeds from left to right, whereas other similar solutions often apply a vertical approach with the patient falling downhill in the care process. In future, there should be an early pre-operative assessment at the time of initial diagnosis of osteoarthritis in order to engage patients in lifestyle change in a timely manner, improve patient care by optimizing therapy, and maximize resilience to the physiological stress of surgery [15,16]. In addition, all the data need to be synchronized to a web-connected portal on a remote server, which could enable personalized care and consultation to be carried out through multimedia messaging. This interaction possibility could increase the transparency for both patient and caregiver and help patients to understand what to expect from the journey; pre-operative expectations have been associated with post-operative dissatisfaction [11].

In line with the previous literature [4], the solution reminds the patient about upcoming events and tasks, reducing the burden of remembering and avoiding possible no-shows [15,16]. As a motivational feature, the digital solution provides a summary of tasks with manual confirmation to foster patient adherence to the fast-track protocol. In future, the digital solution should enable more comprehensive self-monitoring with personalized exercise programs.

Multimedia messaging with in-built video improve patient-provider communication; most current mobile phones have cameras capable of taking pictures with sufficient resolution and quality to detect subtle changes in skin tone, and the doctor is able to observe and identify complications in real-time prior to follow-up visits [12]. In addition, regular video appointments during recovery have been effective in reducing the number of unplanned clinic visits and improving patient satisfaction [13]. In future, however, the digital solution should provide peer support for patients [14].

In line with the previous literature 8], the current clinical pathways are not patient-centric because patient feedback is not solicited in the stages of development, implementation, or monitoring of clinical pathways. In addition, patient experience is not

only patient satisfaction at one point in time but extends over the whole patient journey [7]. Thus, continuous patient reported experience measures outcomes were incorporated across the entire THA/TKA journey from admission to discharge, and beyond [15,16].

An intelligent chatbot functionality and gamified rehabilitation solution (e.g., points, leaderboards, goals and progress visualization tools) utilizing artificial intelligence (AI) for motion sensing could provide many possibilities for further utilization of data [22]. However, there is a need for further randomized controlled trials to increase understanding of the predictors and moderators of gamification, i.e. what kind of gamified designs work in different contexts, and why. Gamified elements could also be applied to create a more engaging experience and thus, increase both engagement to the app use as well as to the target behavior, such as rehabilitation activities [23].

Strengths and limitations of the study

A number of limitations in the current study are, however, acknowledged. During the project, the companies participated in the prioritization process, and the results must be considered with some caution. In general, it is difficult to balance different interests in a short time frame. However, for this reason, less prioritized technical and functional requirements were categorized as future functionalities. In addition, all the ideated requirements are properly documented for future development. Furthermore, patients and caregivers were not included in the prioritization process. In future, patients and caregivers should be engaged to the co-design process.

To achieve credibility, the interviews were audio-recorded and transcribed verbatim. In addition, the study selection was performed by two independent researchers. The data were analyzed and synthetized though inductive content analysis and confirmability was ensured through feedback from the research team. Rigor was ensured by using original quotes from the patients and healthcare professionals. In addition, the sample selection and data analysis process were explained in detail to ensure transferability. Due to similarities in health information needs and preparation for surgery, the findings may be applicable to other surgical journeys.

Recommendations for further research

Due to lack of integrations, there is a lack of accountability [8]. In future, the application could collect and combine sensor data, quality measures, and clinical data to support competitive benchmarking, predict risks, and decide the most effective and personalized treatments [24]. Visualization of the aggregated data could provide further insights and may enhance patients' engagement to their own care. Wider utilization of new solutions is not straightforward, and many issues, such as existing technology infrastructure, integration costs, procurement processes, and legal requirements, must be considered.

Conclusion

The results demonstrate the overall concept of a digital solution for the reference implementation. The uniqueness of the solution lies in the vision of wider integrated systems, which could offer a clinical platform for clinicians to provide patient-focused care remotely, while monitoring patients' progress closely.

Conflict of interest

None.

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