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Digitalization in MedTech:

Understanding the Impact on Total Knee Arthroplasty

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Abstract

Digital Technologies (DTs) in healthcare are of growing relevance for different actors along the patient journey. This paper breaks down the complex landscape of digitalization by focusing on the Total Knee Arthroplasty (TKA). It aims to identify today's technologies and the most promising future trend, assessing the impact on the respective stakeholders. To answer these questions, a structured literature review (SLR) was conducted combining the search term digital AND knee AND replacement with journey OR value OR trend. This resulted in 39 peer-reviewed articles for in-depth analysis. In addition, a qualitative assessment was carried out based on 27 semi-structured interviews (SSI) with six stakeholder groups (patients, surgeons, physiotherapists, industry experts, insurance representatives, regulators) along the patients' TKA journey. The SLR revealed five clusters (3D Printing, Big Data, Wearables, Virtual Healthcare, Robotics) as most recurrent DTs within TKA. The SSIs confirmed that all five clusters are relevant and recognised today. Big Data is considered by the stakeholders to be the most promising DT in the future because of its power to interconnect the other technologies and thereby improve health outcomes. Among the different stakeholder groups, the effect of DTs on their individual roles were perceived differently. Regulatory hurdles and cost-benefit uncertainties were determined to be the most prominent obstacles on the establishment of DTs.

Improvements in patient outcomes is the principal gain from utilizing DTs throughout the patient journey. However, the benefits of switching to DTs require convincing scientific evidence to promote acceptance by all stakeholders in a value-based healthcare system.

Table of contents

List of Tables

Introduction

The total knee arthroplasty (TKA) procedure replaces the natural knee articulation by an artificial joint made of metallic and plastic components. It is recommended when the natural articulation was damaged by arthritis or by trauma. Osteoarthritis (OA) of the knee is one of the key reasons for pain as well as dysfunction affecting patient health (McDonough & Jette, 2010). TKA has proven to be a successful treatment option for patients suffering end-age OA (Jüni et al., 2006). Like all technologies, the TKA procedures have evolved throughout the years. According to Dall'Oca et al. (2017), the idea of using different materials to reconstruct an articulation dates back to the 9th century, where exotic materials like pig bladder and cellophane were experimented without much success. Bone resection experiments in 1860 managed to restore some mobility but with limited joint stability. After the 1950s, subsequent improvements like implantation of tibial plateaus, combination of plastic and metallic parts, and introduction of high-density polyethylene were important milestones to start shaping the TKA procedure. Further advancements throughout the 1970s, like the minimization of surface roughness to reduce abrasion between parts, helped to shape the procedure as it is known today (Dall'Oca et al., 2017).

The advancements exposed by Dall'Oca et al. (2017) show how the evolution in materials and techniques allowed the TKA procedure of today to be well established worldwide. In Switzerland for instance, a total of 15'378 total knee arthroplasties were recorded in 2019 with an increase of 5.1% compared to the previous year as stated by the Swiss Joint Registry (SIRIS). SIRIS registered a total of 100'000 cases during period from 2015 to 2019 with the rate of women being 60.7% and the mean age at 69.5 years (National & Registry, 2020). The growing popularity of TKA procedures performed is also reflected in the United States by the world's largest registry, the American Joint Replacement Registry (AJJR), which shows that 139'991 TKA surgeries were performed in 2019 alone ((AAOS)/AJRR, 2020).

The development of new materials, tools and knowledge contributed to improve the TKA procedure across the decades. Today, the dissemination of Digital Technologies (DTs) is a reality that contributes to improving life quality in different levels, including in healthcare. At home, a person's pulse can be constantly monitored using a wristwatch instead of an analog device, the body temperature with a digital thermometer instead of one containing mercury, and blood pressure can be measured with a digital device instead of a bulky analog one. All this information can be exported to a computer or smartphone which can be connected to a data system or a cloud-based network. It is easily accessible for everyone and can without difficulty be shared with related parties such as doctors.

Digital devices generate value by providing vital information for the user as easily as possible. This information can help to improve health outcomes by allowing individuals to make the decision of looking for a surgeon or hospital, taking medicine, or simply changing habits. Similarly, digital equipment and digital imaging is used in operating rooms to monitor patients during their surgery. This provides information on the actual health condition of the patient as well as indirectly on the outcome and recovery phase. Here again, all information is easily and quickly available and exportable to the device of choice. This helps the surgeon to choose the correct perioperative interventions in order to improve the patient's outcome and quality of life (Bath et al., 2012).

The United States Food and Drug Administration (FDA) defines digital health as a broad scope of technologies that include categories such as mobile Health (mHealth), health information technology, telehealth, wearable devices, telemedicine as well as personalized medicine. These technologies can be used in medical devices or be themselves a medical device. They use computing platforms, connectivity, software, and sensors to provide healthcare as well as other related applications (What is Digital Health, 2020). The innovation needed to offer digital solutions requires costly investments in research and development, regulatory, production, marketing, and other relevant departments. Companies will invest only if they see the potential in offering a new solution that will be attractive for health care professionals (HCPs) and patients. In order to be attractive, the digital solution needs a clear value proposition. Back in 2004, Porter and Teisberg defined value in healthcare as the quality of the health outcomes per unit of money invested. This refers to diagnosing, treating and preventing of health conditions which are unique for each person or group (Porter & Teisberg, 2004). In other words, value-based healthcare rewards the quality of the outcomes, as opposed to a fee-for-service system, which pays only for the quantity of services provided (Porter & Kaplan, 2016). The present study is guided by this value-based healthcare concept and looks at a specific procedure to explore the benefits from a patient-centric view. As Porter and Teisberg pointed out, the true value in healthcare lies in achieving the highest quality with the lowest cost (Porter & Teisberg, 2004). Deriving on the analysis provided by Herzlinger (2006), innovation has the potential to generate better outcomes and increase value. For HCPs and patients, the positive impact in the outcome and costs equation will translate in attractiveness. For the MedTech industry, the challenge is how much they can impact this equation to try to predict market penetration and decide on how much to invest in possible digital innovations. If all these factors align, customers will be experiencing better outcomes for lower prices and the companies will be generating profits with these new solutions (Herzlinger, 2006). Digitalization has the potential to enable the best healthcare to be promptly available to everyone, everywhere and without having negative effects on the existing infrastructure. However, digitalization in healthcare is highly complex and not always consistent. Outcomes, investments, adoption, data privacy and costs are highly debated. The intensity of these debates varies not only with a segment of healthcare, but even with specifics such as a single device or procedure.

Menvielle et al. (2017) define digitalization in healthcare as anything in the field of healthcare using the aid of information technology with the goal of delivering or facilitating better health or health services. The definition itself shows how broad this subject is. Technologies and trends will vary depending on the medical specialization, as well as between procedures within the same specialty. It is possible to perform high level analyses on the general topic, but if specific technologies and tendencies are to be named, it is necessary to narrow the topic down.

Although this is an established and successful procedure, approximately one out of five patients are not satisfied after the treatment. The most common causes for dissatisfaction are persistent pain and functional limitations (Kahlenberg et al., 2018). A wide range of current and new digital solutions is attempting to improve this situation. How established these solutions are today and which technology could be the most promising for the future is the subject of ongoing debate. To bring clarity into the debate, this paper will break down this topic by exploring the following research questions (RQs) within the TKA journey:

- RQ1: What are the most relevant digital trends today?
- RQ2: What is the most promising technology for the future?
- RQ3: What value do these technologies generate for the key stakeholders?
- RQ4: How are these technologies affecting the role of the key stakeholders?
- RQ5: Why are these technologies not yet mainstream and broadly established?

To answer these questions, we will analyze which topics appear most commonly in the literature concerning TKA. This will be done by researching related technology terms in the University of St. Gallen's online library system. A structured literature review (SLR) will then allow us to explore DTs, group them in clusters and summarize each of their main aspects to describe the latest scientific findings. Based on these findings we will reach out to stakeholders influencing the TKA journey in Switzerland to enhance our findings and understanding of each cluster from the perspective of experts.

This paper will show that, although a multitude of digitalization trends within the TKA are discussed today, not all of them are equally relevant in the future. The future TKA journey takes place in an interconnected ecosystem of technologies. Stakeholders need to acknowledge that this represents a change in roles and relevance in their contribution to this journey.

Background

The background research showed that the analysis of digitalization in healthcare is approached mostly from a top-level and international perspective. In these cases, the studies cover multiple medical devices over a certain period and reveal what is generally happening in the industry. When narrowing down to the TKA technologies, studies were found which were conducted in one country with the aim to summarize the tendencies identified for that location in particular. Another common approach is to choose one specific well-known digitalization technology in TKA and analyze the impact on the behavior of a group of individuals. In this case, the impacted group can be composed by patients and their relatives, HCPs, MedTech and technology organizations such as Google and Apple. The behavioral studies include, for example, patient compliance with instructions, exercise progression, or simply patient satisfaction level. From the perspective of other stakeholders, behavior can be understood for example as general acceptance towards digitalization. Another recurrent type of study is to choose a specific kind of technological device and investigate how it impacts the procedure. This kind of study targets an audience with a deeper medical background.

Angerer et al. (2019) analyzed the healthcare industry using the Winterthur Institute of Health Economics (WIG)-model. This method divides digital healthcare in four main categories: trend health, e-health, tech-health, and data health (Angerer et al., 2017). Each category is broken down into a total of 12 sub-groups. In their analysis, the authors perceive Switzerland in a unique position with the necessary infrastructure supported by a strong MedTech sector to embrace digitalization (Angerer et al., 2019). However, the country ranks below average in the maturity of digital health, being placed in position 14 out of 17 European countries (Thiel et al., 2018). Another more simplistic but also realistic approach is introduced by Boni (2018) who defines medical devices, diagnostics and medical imaging as the three segments of MedTech. These segments are all being impacted by digitalization. The author writes about minimally invasive surgery as a central topic being transformed by digitalization (Boni, 2018).

It is not possible to talk about digitalization without talking about data. Jayaraman et al. (2020) use the term Healthcare 4.0 to define the data ecosystem around digitalization in healthcare. The authors demonstrate that data from social media, devices, simulations and imaging systems constitutes the foundation of a pyramidal model. Digital knowledge representation is listed in the middle of this pyramid, with platforms and databases like PubMed, lexicons, and ontologies. At the top of the pyramid the authors present artificial intelligence (AI), where information is automatically generated using the lower levels of the pyramid. The study mentions several possible applications of all data using examples such as virtual healthcare and wearables for health monitoring (Jayaraman et al., 2020).

Aside from data management and data privacy, economic interest is a crucial factor driving digitalization in healthcare. To increase adoption and investments in DT, it needs to be proven that this transformation can, for example, reduce costs and increase profits. Herrmann et al. (2018) selected a practical approach to define changes in the healthcare industry. The authors looked into the top healthcare and technology organizations as well as start-ups within the Forbes 2000 list and summarized the main digital projects that these companies were working on. These projects addressed six main customer needs: adherence, prevention, diagnostics, patient engagement, treatment and lifestyle (Herrmann et al, 2018). Herrmann's article does not clearly state if the customer is the patient, the hospital, or the surgeon. The role of patients as the customer and how this role is changing with digitalization is more clearly discussed by Hermes et al. (2020) in the context of emerging platform ecosystems. Using data analysis, the authors studied 1'830 healthcare organizations and were able to derive eight new roles. These new roles are data collection technology, information platforms, market intermediaries, service for remote and on-demand healthcare, augmented and Virtual Reality (VR) provider, blockchain-based personal health record cloud service provider and intelligent data analysis for healthcare providers. These are all new roles which have emerged and evolved from digitalization. They empower patients who have more information to be part of the decisions and have more touchpoints with stakeholders during their health journey (Hermes et al., 2020).

Technological improvement in medical technology can provide a better outcome for the patient and deliver services in a more efficient way while considering the patient's individual needs. According to a Frost & Sullivan report, patient engagement is potentialized through solutions like apps, mobile portals, messaging and wearables. These patient engagement solutions are forecasted to achieve a worldwide annual growth rate of up to 20.9% from 2020 to 2025, reaching a potential revenue of US $30.2 billion. They are all technologies with potential to offer individualized healthcare. The growth perspective could be even higher if the challenge of resistance to technology adoption could be overcome. Technology for patient engagement solutions is perceived differently depending on the region. In North America for example, the adoption rate can be as high as 90% while in Latin America it can be as low as 20%. The report highlights, however, that this situation can change depending on special circumstances such as the example of COVID-19, when Virtual Healthcare became one of the only options available (Mathur, 2020). Another study, also from Frost & Sullivan, looks specifically into the telehealth potential in Europe and assigns an annual growth of 29.4% from 2020 until 2025 with annual revenues of up to US $20.7 billion. The main enabler of this growth is the utilization of telehealth to contain part of the increasing healthcare costs by reducing the amount of in-person consultations and optimizing the time dedicated to each patient (Mathur, 2021).

In the present study it was decided to focus on the Swiss MedTech industry as a sound reference for understanding what is happening globally. Considering that Switzerland exported CHF 12 billion worth of medical devices in 2019 according to a study by the Swiss Medical Technology Industry (SMTI) group (Wettstein et al., 2020), it can be assumed that the transformations ongoing in the Swiss industry reflects the international developments up to a certain level. When it comes to digitalization, the SMTI Report 2020 points to 18 technology trends divided in five overarching categories: product innovation, manufacturing method, diagnostics, therapies, and healthcare. The authors point out that recurring components of these trends are data management and interpretation, automatization, personalization, and remote treatment. For products in particular, the SMTI team identified smart devices as the main trend, followed by material innovation, substitution technology, data recording and individualization. The order of relevance of these trends varies when the article looks specifically through the lens of manufacturers, suppliers and traders. In addition to this, depending on the perspective, these stakeholders consider some of these trends as threats to their business practices (Wettstein et al., 2020). The SMTI report and other articles in scope also mention data processing, Big Data and data acquiring as a recurring top trend. This is not surprising, as digitization and innovation are most often combined with data. Collins (2016) looked into strengths, weaknesses, opportunities and threats of Big Data from a pharmaceutical perspective which is believed to be also applicable to medical devices. He concludes that Big Data has the power to improve healthcare, for example, by improving decision making and individualization based on real world evidence. This does not come without discussions and issues around data privacy and potential unequal benefit distributions for patients and practitioners depending on their ease of handling the technology. Where threats are concerned, the author emphasizes that collecting and analyzing Big Data from real situations could show that many products and practices are inefficient, ultimately making some activities and jobs redundant. Furthermore, once Big Data is collected and stored, it can become a source and a target for ethically questionable activities (Collins, 2016).

The literature covered in this background chapter did not manage to bring together DTs applied to the level of a specific, yet most commonly performed procedure. The closest example to a comprehensive research with a specific application is provided in the article "New Technologies in Knee Arthroplasty: Current Concepts" by Batailler et al. (2020). In this article an extensive literature review identifies new technologies playing an important role in TKA and analyses the impact and outcomes within different stages of the patient journey. The authors define patient-specific instrumentation (PSI), patient-specific knee prothesis, sensors, accelerometers and robotic-assisted knee arthroplasty as the most current technologies. Although these technologies are promising, there is no unanimity in the literature regarding the direct benefits as the long-term results and data is still limited (Batailler et al., 2020). Although

Batailler et al. (2020) provide an extensive technical perspective, the practical aspect remains largely undiscovered.

Research Methodology

A structured literature review (SLR) was used to explore foundational data. The results were elaborated through semi-structured interviews (SSIs) with various key stakeholders along the TKA patient journey.

Structured Literature Review

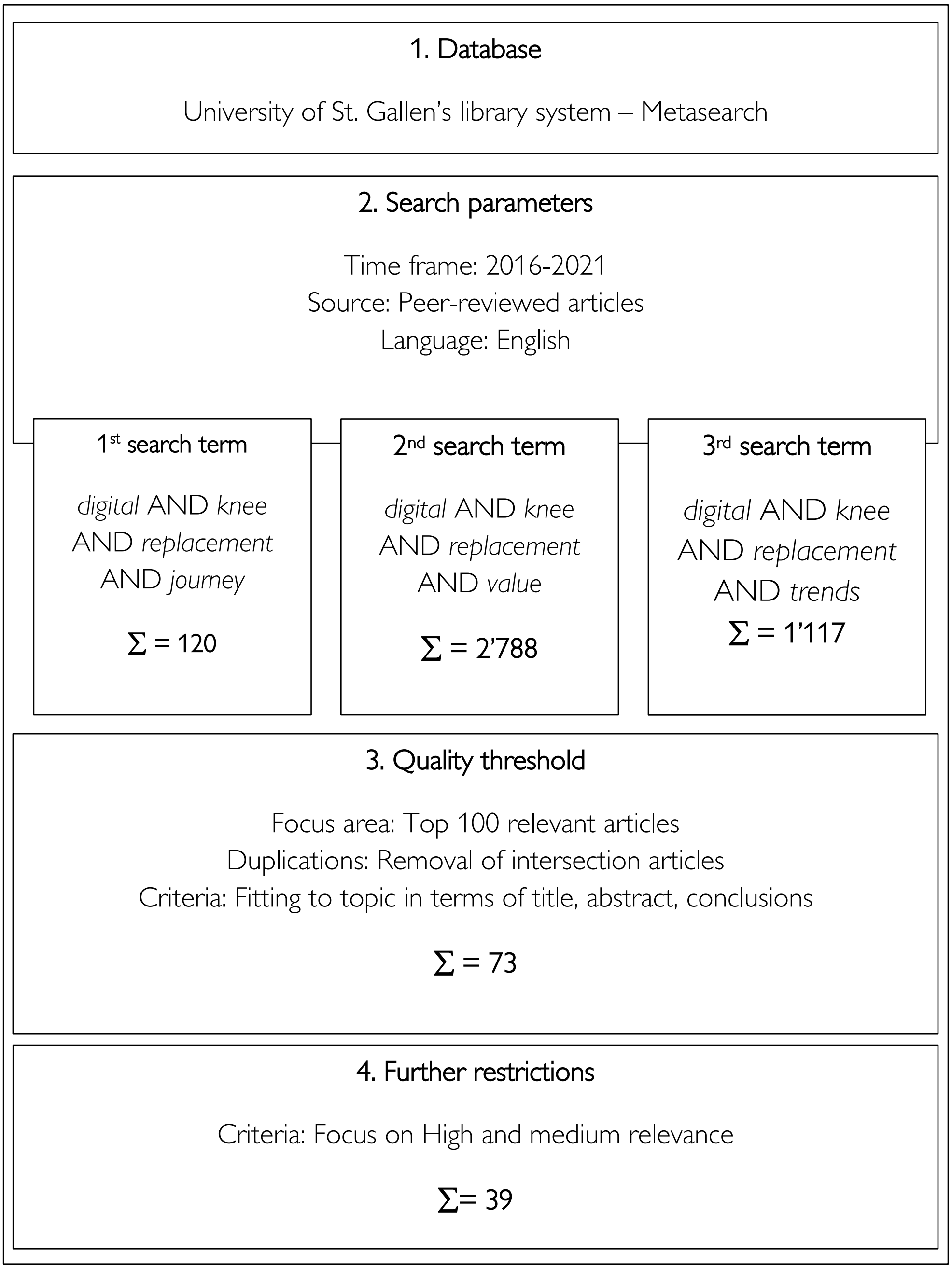
The first parameter defined for the SLR was the search tool used. Considering that the goal was to approach the digitalization in the TKA journey from a business perspective, the selection of the University of St. Gallen's library system was a reasonable choice. The platform is well connected and provides access to a majority of the relevant human-science and business journals. It was decided not to limit the search to specific journals, reasoning that to do so risked biasing the search.

Once the search platform was defined, suitable search terms were defined. The objective was to focus on the knee replacement procedure and the DTs around it. This reasoning led to the first fragment of the search term which was digital AND knee AND replacement. These three words are the core of the research topic and were therefore used in each of the search queries. Some of the key questions behind the idea for this research project were devised to understand how digitalization is changing the patient journey, how it is affecting value-based healthcare and, naturally, which trends are impacting it. With three questions in mind the following three search terms were chosen:

- 1st search term: digital AND knee AND replacement AND journey
- 2nd search term: digital AND knee AND replacement AND value
- 3rd search term: digital AND knee AND replacement AND trends

Search term 1 was the one which was first used to obtain a reasonable number of results. However, using this expression without further filters would have produced thousands of results. Digitalization is a dynamic field, so there was a higher interest in current situations rather than those that had occurred too long ago. As a result, the search was limited to articles published starting with the year 2016. The choice to examine only peer-reviewed articles was also a fundamental decision to increase the quality of the material analyzed. The last filter applied, for clearly practical reasons, was to select only articles for which the full text was available online. Search term 1 using journey yielded in 120 articles. By reading the abstract and, if necessary, analyzing crucial parts of the article in more depth, it was determined whether or not the article was relevant to the present research. Non-relevant articles were the ones that, although containing the search terms, had no meaningful reference to technological trends. Relevant articles were those that experimented with and evaluated any DT tools or focused on stakeholders' needs and discussed how these could be met through technology. Figure 1 illustrates the executed SLR with the yielded articles for each search term.

Figure 1: *Structured literature review approach*



No particular filter was defined to influence the sequence in which the articles appeared in the SLR. This means that they were ordered according to relevance as they appeared using the standard configuration of the search tool. When asked about how exactly this relevance is assigned, the HSG library provided a thorough explanation of dynamic and static elements used as ranking criteria which is displayed in detail in Appendix D. The analysis of the first 100 articles showed that the relevant literature for this research was concentrated within the first 50 articles. To define a sufficient range, the focus area was thereby set to the first 100 articles for all three search terms. The original search for term 2 and 3 had resulted respectively in 2'788 and 1'117 articles. For all three search terms, the same filter and relevance criteria were applied. The literature search yielded 73 articles for deeper analysis as outlined in the next chapter.

Cluster Structuring

The 73 articles in scope were assessed based on the results of each article, focusing on the following steps:

1) A short summary for each article with the main findings.
2) The patient's journey simplified touchpoints applicable to the article: diagnosis, pre-operative phase, surgery and post-operative phase.
3) The stakeholders affected or involved, from the following groups: patients, surgeons, physiotherapists, industry experts, insurance representatives, regulators
4) Keywords representing the category of the digital trend applicable to the article.

Once the data for steps 1 – 4 was gathered and documented, in a second and more thorough analysis the articles were rated by relevance according to the following criteria:

- High relevance: articles which have as main subject the impact of a DT on one or more of the journey touchpoints: diagnosis, pre-operative, surgery, post-operative.
- Medium relevance: articles which have DTs as one of the alternatives being studied or where its conclusion referred to DTs as a possible solution.
- Low relevance: only minor touchpoints with DTs or no relation between the research question(s) and the DT.

Since the articles rated with low relevance were only indirectly related to DTs, it was decided to exclude them from further analysis. Once this summary was completed, the information was used to define which clusters were recurring. To do this, common keywords, stakeholders, and journey touchpoints were grouped together. Any assumptions taken to reach the final clustering are outlined in the results.

Exploration via Semi-Structured Interviews

To allow deeper exploration of opinions and perspectives, SSIs were set up with key stakeholders along the patient journey. The application of SSIs enabled comparability within and between stakeholders while also allowing conversation to go beyond the topic as it progressed (Saunders et al., 2012).

Settings and participants

All participants who have touchpoints with the TKA journey, including the patients themselves, were selected as the sample stakeholders. Building on the TKA patient journey and augmented with roles from the SLR, the key stakeholders were then selected. This included patients, HCPs such as surgeons and physiotherapists, industry professionals, insurance representatives and regulators. The broad range of stakeholders selected ensured a thorough assessment of the TKA journey, which was determined to be most suitable for this research project. Three stakeholders were defined as the targeted sample size for each group.

For a stakeholder to be involved in the research project, the inclusion criteria were as follows: (a) relevance of position (b) knowledgeable to some extent about the TKA journey, (c) preferably based in Switzerland. Within the individual stakeholder groups, the following criteria were adhered to:

- Patients: recent TKA within the last five years
- HCPs: surgeons and physiotherapists as members of major Swiss clinics as well as national associations
- Industry: senior strategic management positions as well as operational functions in Marketing and Sales from some of the largest multinational MedTech companies
- Insurances: senior management positions from the top five Swiss insurance companies
- Regulators: representatives of the BAG and European Commission

Interview guide

Interview questions as presented in **Appendix C** were generated from the research objectives in combination with the identified DT clusters from the conducted SLR. The interview questions were spilt between forced-choice questions for 1 and 2, and open-end questions for 1.1, 2.1, 3, 4 and 5. The predetermined answers of questions 1, using a list, and question 2, using a selected category, aimed to simplify and to some extent quantify comparison. The follow-up questions 1.1 and 2.1 provided the opportunity for the respondents to share detailed background insights on what had mattered to them in relation to their choices. This method of SSI also allowed discussions in areas which had not been considered by the closed questions 1 and 2, thus providing practice-related insights alongside the theory. The interview was pilot tested with two HCP's and one MedTech professional, all of whom were not part of the final interview group used for the analysis.

Data collection

The interviews all took place between the 31st of May 2021 and 15th of June 2021. At the beginning of each interview, the assigned author described the purpose of the study and asked for consent to further use the video-recorded material to be subsequently transcribed and anonymized. The interviews were scheduled for 30 minutes and took place online or in-person. Online sessions were viewed as more convenient as they enabled interviewees to connect whenever their schedule permitted, exchange in a safe environment due to COVID-19 implications and thereby creating a higher willingness to participate.

Data analysis

For the purpose of analysis, a Qualitative Content Analysis based on Mayring (2000) was conducted, based on a three-step approach of paraphrasing, generalization and reduction in inductive category formation. This involved creating a coding tree to identify patterns and meanings within and between the individual stakeholder groups using the occurrence of word codes. After systematic comparison of the coding across all response transcriptions, sub-categories were developed (Mayring, 2000). For the force-choice questions 1 and 2, the frequency of answers was used to determine the most popular DT categories. Finally, the identified sub-categories were connected to the corresponding stakeholder groups.

Results

The results of the SLR show that some DTs are recurrently being studied in the TKA journey. Chapter 6.1 outlines how the common points of these studies were combined into five DT clusters. In chapter 6.2, the findings of the SSIs are presented in the perspective of the different stakeholder groups.

Top-Level Digital Technology Groups

Based on the 39 studies identified and analyzed, five DTs can be defined that are of great importance in the context of TKAs. Those clusters are 3D Printing, Big Data, Wearables, Virtual Healthcare and Robotics. Several peer-reviewed articles covered a combination of DTs. A group assessment of each articles' core topic was performed to assign them into main DT clusters as outlined in Appendix A. DTs commonly share the potential to permanently change the traditional methods and processes found in the TKA journey. The pre-operative phase includes diagnosis, communication and information flow, preventive treatment measures or ultimately the decision to perform the intervention.

Numerous new opportunities have emerged to interact with patients through digital channels and make recommendations regarding the need for surgery or alternative treatment approaches based on collected health data. If an operative intervention is eventually required, surgeons can now for example make use of robotic systems that not only serve as a hand-held navigation assistance for the various steps, but also permit precision cutting and drilling with unprecedented accuracy. Patients have the opportunity to benefit from individualized knee implants made possible by precise scans and 3D Printing processes that are perfectly adaptable to anatomical conditions. In the post-operative stage, sensors can be used to track the stress on the operated knee and continuously monitor the healing process. Rehabilitation can be enhanced using physiotherapy-assisted mobile apps or video check-ins to stay in connection with HCPs. The five identified DT clusters derived from the 39 evaluated studies are described in more detail below.

Cluster A: 3D Printing

3D Printing is a method that adds material layer by layer, producing highly complex geometries with relatively little input and waste. The input used is a digital file that can be read by the 3D Printing machine. The SLR found five articles having 3D Printing as core topic and two articles having Robotics as core subject but important overlaps with 3D Printing. The advantages of 3D printed components compared to regular manufactured ones are the possibility to individualize them for a perfect anatomical fit, as well as potential cost and time reductions (Beal et al., 2016; Sezer et al., 2021).

Most articles in scope view the main application for 3D Printing in TKA to be the production of patient specific instruments (PSI). Secondary applications are to produce models of the patient's anatomy to plan or explain the surgery, and patient-specific knee prothesis. Although used in different medical specialties, the widest usage of 3D Printing is in knee surgery.

In a holistic literature review of 227 articles about 3D Printing in medicine, Tack et al. (2016) showed that in 30.7% of all articles, the application is in knee orthopedics. In the literature analyzed, the information used to produce the digital models is predominantly generated by computer tomography (CT), magnetic resonance imaging (MRI) and standard x-ray. Because it originates from digitalized models, the use of PSI is considered to be a kind of computer assisted surgery (CAS) (Sezer et al., 2021). A review by Beal et al. (2016) points out that CAS is composed of robotic assisted surgery and PSI. While the first uses CAS only during surgery, the latter uses CAS already preoperatively to plan 3D models, instruments and implants (Beal et al., 2016).

All articles analyzed identify the precise alignment and balance of the knee components to be the main challenge in TKA, where a maximum misalignment of three degrees between the components is allowed (Beal et al., 2016; Sezer et al., 2021). The articles mention as the underlying concept behind PSI that there are 3D patient-specific cutting-guides and models that can facilitate optimized bone resection and the removal of certain surgery steps and measurements. This is possible because PSI instruments and models have already considered the individualities of each patient's anatomy. Theoretical advantages of PSI are improved clinical outcomes because of better balance and alignment, a reduction in surgery duration due to partial elimination of certain decision-making during surgery and a reduction in the amount of instrument trays, possibly resulting in a lowering of surgery costs. However, the literature encountered concurs that there is no solid evidence to prove these advantages.

In another review, Beal et al. (2016) also find conflicting information regarding surgery duration, with some studies pointing out a statistically significant time reduction and others pointing out no difference at all. There is no mention about the increase in duration of surgery when using PSI. Perhaps one reason why there is no noted improvement in the surgery duration is that the review also found a study that pointed to an error rate in PSI of up to 27%, requiring additional steps and checks during the operation (Scholes et al., 2014). With regards to costs, the authors found studies pointing out indirect costs of up to US $1'500 as a result of additional imaging and manufacturing. No significant evidence of improved clinical outcome with PSI could be found in their review (Beal et al., 2016).

In more targeted studies, the literature search identified a study by Tian et al. (2018) comparing 31 patients operated with PSI to a control group of 31 patients operated on with conventional TKA. The authors compared the outcome in surgery duration, knee alignment, clinical outcome, and postoperative wound fluid drainage. No significant difference was found for the first three points. Only the drainage volume was significantly lower for the PSI group and this could be a result of fewer surgery steps (Tian et al., 2018). Another study by Kwon et al. (2017) identified a significantly reduced surgery time (63.9 ± 13.6min) for a group (n=68) of patients operated with PSI when compared to the conventional instrumentation (n=50, 82.8 ± 24.8min).

As mentioned in the previous paragraphs, when it comes to clinical outcomes the literature is not unanimous about the advantages of operating with PSI. One study by Ogura et al. (2019) shows, however, that for the less invasive and new technology of bicompartmental knee arthroplasty, the clinical results when working with PSI are promising when compared to conventional TKA. The authors point out, however, that a long-term clinical follow-up is still needed to make firm conclusions (Ogura et al., 2019). Looking at a business feasibility perspective, Randhawa et al. (2021) described a case study of a company that successfully shifted its business model to mass production of customized 3D printed implants for knee sarcoma patients, showing that it is possible to operate profitably with this technology (Randhawa et al., 2021).

Cluster B: Big Data

Big Data refers to the ability to generate, collect and store a large amount of complex data in a structured manner and then process it for extensive analysis activities (Collins, 2016). For decades, data has been collected by a wide variety of institutions in every conceivable area of life, be it personal, scientific, or industry-related data. However, the huge amounts of data have barely been exploited so far due to technical limitations or lack of interconnectedness. Rapid advances in the development of powerful hardware and the emergence of AI have ensured over the last few years that the available and mostly unmanageable data pools can now be fully leveraged for the first time. Collection and analysis of patient or procedure data also offer great potential to the healthcare sector. While the industry benefits from innovative insights and cost-saving opportunities, patients can benefit from tailored healthcare services and greater product safety. The research provided eight studies which looked at the use of Big Data along the TKA journey. Highlighted benefits of Big Data were improved processes as well as cost savings (Sershon et al., 2017; van Kasteren et al., 2018), ability to help with decisions (Price et al., 2019), and newly gained medical insights (Malchau et al., 2018).

Sershon et al. (2019; 2017) conducted a study to determine whether a patient's height, weight, and gender can predict the necessary size of the TKA implant. After analyzing data from 3'491 patients and associated knee surgeries combined with the manufacturer's implant-specific dimensions, they were able to create a predictive model that could reliably forecast the correct product-size with a deviation of only one size. For hospitals, the application of such a data-driven model would enable optimized inventory management and preoperative planning. The resulting cost savings could contribute to the hospital's profitability and value creation (Sershon et al., 2019; Sershon et al., 2017).

Data can also potentially be used to support decisions about whether TKA is even necessary for a given patient and economically reasonable as a whole. Price et al. (2019) observed that often times patient-reported outcome measures (PROMs) are used in deciding on whether to operate or not. However, there is no real evidence that PROMs are sufficient for surgeons to suggest and schedule an operation. In order to quantify these measures and define a threshold of when a TKA is worthwhile, Price et al. developed the Arthroplasty Candidacy Help Engine (ACHE) tool. The ACHE tool uses a combination of patient-specific medical data, data from the Oxford Knee Score (OKS) and cost-related data of a TKA to calculate the threshold. If this threshold is put in relation to the cost per quality-adjusted life-year (QALY), statements about the cost-effectiveness of an operation can be made. Price et al. surmise that while the ACHE tool does not replace the existing decision-making process it has the potential to support surgeons in giving more reliable suggestions (Price et al., 2019).

The extent to which information along the TKA journey can be used more efficiently based on better data management and application of technology was examined in another study by van Kasteren et al. (2018). This involved a qualitative multi-stakeholder survey with 34 respondents from surgery, physiotherapy, and patient populations. It was found that interactions between patients and medical staff generate a lot of data that could be used to optimize process flows. For example, in the preoperative phase, waiting list management could be improved, an aspect which currently leads to high annual opportunity costs due to inefficiencies. Another application would be tailored information that can be passed on to patients and thereby helping them during rehabilitation after surgery. Other conceivable scenarios include automated monitoring of health data to optimize the length of postoperative hospital stays or early recognition of complications (van Kasteren et al., 2018).

Another interesting opportunity of Big Data has been explored by Malchau et al. (2018). The study deals with national and local arthroplasty registries that have been collecting data from joint replacements (incl. TKAs) for decades. To benefit more from the data sets, international collaborations between different registries are increasingly formed. This creates an unprecedented pool of quality data, patient data, clinical data, and best practices. Thanks to technological advances and AI, these large volumes of data can be aggregated and analyzed so that HCPs, manufacturers and ultimately patients can benefit from new insights (Malchau et al., 2018).

Cluster C: Wearables

Wearables are defined as hardware devices that capture patients' health data as part of human behavior analysis. These devices can collect and share users' health data with a dedicated HCP in real-time, enabling predictive capabilities and personalized feedback. Some of the major sub- categories of Wearables include smartwatches, wristband sensors, smart glasses, e-textiles and health monitors. They all rely on embedded sensors such as accelerometers for capturing vibration and motion, and gyroscopes for measuring linear accelerations and angular velocities (Jayaraman et al., 2020). The SLR yielded a total of eight studies which explored Wearables utilization throughout the TKA patient journey. Research revealed that some of the major benefits were minimization of human resources (Correia et al., 2018; Logishetty et al., 2019), driving personalized and effective physical activeness (Karas et al., 2020; Li et al., 2017; Van Dijk-Huisman et al., 2020), promotion of data-driven interventions by HCPs (Logishetty et al., 2019); (Schotanus et al., 2017) and maximizing patient access while minimizing costs (Correia et al., 2019; Correia et al., 2018; Schotanus et al., 2017).

Two delayed-control designed studies (Karas et al., 2020; Li et al., 2017) set out to unlock the potential of the consumer-grade Wearable Fitbit within the TKA patient journey. One large-scale study with 1'324 individuals looked at detecting behavioral measurements such as steps sum, heart rate and sleep efficiency score (Karas et al., 2020). The second research took a multi-layered approach by adding telephone counseling as well as utilization of a research-based accelerometer SenseWear Wearable to evaluate sedentary and so-called light activities. Results show that four weeks of post-operative activity tracking data can carry substantial information to ensure better long-term recovery for patients (Li et al., 2017). The observations of both studies also provided evidence that tracking the level of activity before the elective surgery had a positive correlation with post-surgical functional recovery. Going beyond the standalone Wearable, Li et al. (2017) highlighted that addressing skills such as action planning and problem-solving are essential to further encourage physical activity behavior .

Three studies (Correia et al., 2019; Correia et al., 2018; Schotanus et al., 2017) suggest that non-invasive triaxial accelerometer-based Activity Monitors (AM) can be successfully used to provide physical activity insight during pre- and post-operative stages. To maximize access and simultaneously minimize costs, home-based rehabilitation with digital assistance such as Wearables has become a favoring therapeutic option as the aforementioned three studies confirm. Within a home-based rehabilitation setting after TKA, one intervention study (Correia et al., 2018) compared the application of a digital biofeedback system using inertial motion trackers, a mobile app, and a web-based portal, with in-person supervision within an eight-weeks assessment period after TKA surgeries. The single-center, parallel-group, feasibility study measured several outcomes with the Knee injury and Osteoarthritis Outcome Score (KOOS).

This score assesses the patients' opinions on their knee and associated problems, the superior score being compared to the conventional study group (Correia et al., 2018).

Their follow-up study reassessed patient outcomes at three and six months post-surgery and revealed that all other outcome measures apart from the KOOS, such as the Timed Up and Go and knee flexion while standing, showed significant clinical improvements. The authors implied that this is due to an early and intensive rehabilitation program guided by Wearables. Overall, the study demonstrated that patient empowerment and engagement can significantly increase when using wearable devices as part of an integrated digital ecosystem (Correia et al., 2019).

Another study by Schotanus et al. (2017) discussed the significance of added value by tracking physical activity parameters during the early post-operative TKA stage. The authors argued that conventional PROMs, such as the Oxford Knee Score, the New Knee Society Score, and the KOOS, failed to detect subjective changes such as pain implications on recovery progress. Patient encouragement by using AMs after discharge has a twofold benefit. It allows an objective analysis of the physical activity and thereby provides additional insights into existing PROMs. Whereas accelerometry-based AMs are commonly validated on the basis of healthy adults and show limited sensitivity to measuring slow gait, researchers from the Maastricht University Medical Center set out to explore Wearables in combination with mHealth tools offered to hospitalized patients (Schotanus et al., 2017).

The applied mHealth tools named Hospital Fit was able to tailor the needs of the patients and provide activity-based insight features such as lying down to sit, sit to lying down, sit to stand, walk and walk stairs, and consequently offer physiotherapists the option to provide patient-centric exercises and activity suggestions. They managed to demonstrate higher odds of functional recovery on post-operative day one, at the same time increasing patient activeness time and engagement during hospitalization (Van Dijk-Huisman et al., 2020).

As a distant interface with Wearables, an individual study by Logishetty et al. (2019) explored the application of an Augmented Reality (AR) platform with live holographic orientation feedback overlaying the real-world vision of the wearer. It was applied to help track hand movements and implant positioning as a training tool for surgeons to improve the accuracy of acetabular component positioning in hip implants. The researchers found that the application of AR in training as an adjunct to expert guidance in the operating room results in similar accuracy outcomes to conventional training methods. The key benefit hereby is that essential surgical skills can be acquired in an unsupervised setting, promoting AR as a highly valuable training tool for bone cuts and implant orientation. The study concludes that this technology can also be applied to a TKA setting (Logishetty et al., 2019).

Cluster D: Virtual Healthcare

Traditional, individual, acute and facility-oriented healthcare approaches are transforming into interconnected and remote interaction systems between patients and HCPs to facilitate patient care (Hermes et al., 2020). Virtual Healthcare or Virtual Health Technologies (VHT) in orthopedics is understood as overarching description of fields such as electronic forms (E-forms), teleconsultation, remote patient monitoring (RPM), VR, mHealth and website deliveries (Haq et al., 2020). A total of 10 studies were identified by the SLR that could be allocated to the aforementioned sub-category fields of VHT.

The studies discovered some of the major benefits to be improving patient education (Haq et al., 2020; Higgins et al., 2020; Parkes et al., 2019; Saunders et al., 2021), creating significant cost-savings on avoidable costs (Rosner et al., 2018), freeing up valuable resources (Jansson et al., 2019; Naeemabadi et al., 2020), improving pain control (Pronk et al., 2020; Wang et al., 2019) and driving personalized healthcare (Kungwengwe & Evans, 2020).

The widespread effectiveness of technology-assisted rehabilitation, specifically within the field of telerehabilitation, demonstrated statistically significant improvements in pain reduction for TKA patients. In addition, Wang et al. (2019) assessed that timeliness for discharge can reduce potentially avoidable healthcare costs, mortality, and readmissions. A participatory design study by Naeemabadi et al. (2020) highlighted that for telerehabilitation to be successful, high user-friendliness is required to permit greater flexibility for all users and provide a sense of security for patients when relying on asynchronous communication (Naeemabadi et al., 2020). By assessing large national patient claim data to determine cost implications, one study by (Rosner et al.) discovered that automated digital engagement programs in combination with remote guidance and telemonitoring were able to provide significant cost-savings and reduce potentially avoidable costs, admissions and complications. Multifactorial reasons such as early detection of emerging complications via proactive two-way remote guidance as well as the chance to serve smaller pieces of health information at the time of greatest relevance helped increase adherence and foster patient engagement. The study pointed out that engagement via remote monitoring in the absence of remote guidance may only have limited effects and therefore it needs to be delivered coherently (Rosner et al., 2018). Another qualitative interview study revealed that additional communication methods, such as software robots, so-called chatbots, could return ready-made response options for frequently answered questions, thereby freeing up valuable resources of HCPs and delivering controllable qualitative health information (Jansson et al., 2019).

Van Kasteren et al. (2018) described that DTs can enhance the cocreation of value at different stages of the patient's TKA journey. Results showed that patients have difficulties recalling key information during time-poor and information-rich patient-clinician interactions. Here the patients' information requirements and intervention goals need to be tailored to the stage of the TKA journey while also driving technological solutions to do the same. The authors argue that mHealth solutions delivering the right information at the right time are well-suited to providing real-time care (van Kasteren et al., 2018). One important application field of VH is pain control and correlated opiate usage during the first two weeks after surgery, a period when patients can experience uncertainty and feel left alone after discharge (Pronk et al., 2020).

Haq et al. (2020) revealed that from a HCPs perspective, the most promising technologies were mHealth and E-forms in the pre-operative TKA stage for triaging and delivering patient reminders. They clearly pointed out that lower-risk patients seeking health information for educational purposes and reduction of travel time are noteworthy beneficiaries of these technologies (Haq et al., 2020). In another study, Parkes et al. (2019) uncovered that patients claim that this "click and go" format of mHealth solutions seems suitable to patients not experiencing difficulties, however face-to-face interactions for concerns and problems are still deemed to be essential (Parkes et al., 2019). For mHealth, one of the biggest challenges remains in digital illiteracy specifically when considering the typical advanced age demographic of TKA patients (Haq et al., 2020; Parkes et al., 2019). A recent study by Saunders et al. (2021) discovered that by following an eHealth program based on electronic health data and E-forms during the pre-operative stage, patients could be provided with more realistic expectations and understanding of the post-operative period. The patient-centric education and guidance of the surgical journey resulted in patients feeling "well informed" and was therefore recommended to be a viable option for enhanced patient support (Saunders et al., 2021). By using mHealth, patients were able to actively control and track their pain experiences and as a consequence significantly reduce their opiate usage within the discharge phase (Pronk et al., 2020).

Kungwengwe and Evans (2020) assessed the combined benefits of Wearables and mHealth. They used a mobile and wearable platform, adopted behavioral design principles and gamification theory by carefully analyzing and understanding the user journey. Here the wearable sleeve continuously monitors knee kinematics during exercises and transmits them to an app in form of actionable insights at the same time allows a detailed evaluation over a dashboard. The system combines both opportunities and benefits of Wearables and mHealth technologies for and revealed an improved personalized rehabilitation experience (Kungwengwe & Evans, 2020).

One retrospective analysis by Higgins et al. (2020) of a consecutive series of 1'256 TKA patients set out to capture the implications of Length of Stay (LoS) and PROMs by applying patient engagement and pathway management solutions. The digital innovation ecosystem was designed to engage patients throughout their treatment while delivering relevant education and information and included the opportunity for them to maintain contact with their healthcare providers. They found that by streamlining the pathway, integrating the solution and removing processes with low added value, a significant reduction in LoS from a mean of 6.7 days to 4.7 days (-30%) could be achieved. With readmission and complication rates being similar, the analysis revealed a significant reduction in reoperation rates within the first 60 days while using the digital platform Care4Today (Higgins et al., 2020).

Cluster E: Robotics

Robots have already found their way into numerous industries. They have become an indispensable part of the production halls of automobile manufacturers, aviation, or the food industry. Robots are used especially when there are activities that require special precision, reproducibility, or sterility but also or repetitive, trivial or potentially dangerous activities. Thanks to these qualities, Robotics also offers great potential for application in the healthcare sector, for a significant part in the orthopedic and surgical environment, in particular regarding navigation assistance, precise incisions, positioning and alignment of implants or minimally invasive procedures (Jacofsky & Allen, 2016).

A total of nine studies that address the deployment of computer- and robot-assisted TKAs were found. At the core of all the studies the question analyzed is the extent to which robotic systems can improve conventional TKA operations. The three factors quality-improvement, cost and time play an overarching role. However, there is disagreement among the various authors and their research findings as to whether Robotics add true value to the TKR journey.

Sezer et al. (2021) examined the extent to which CAS are used in a TKR and the impact of this technology when compared to conventional methods. For this purpose, current literature was analyzed and different technologies such as image-based navigation, imageless navigation and hand-held systems were considered. Although the first CAS were used for TKRs in the late 1990s and have been steadily developed since then, the study concludes that the superiority in clinical or patient-reported outcome measures of CAS over conventional surgery has not been clearly demonstrated. Moreover, due to expensive equipment, increased pre-operative 3D scans, and longer surgery times averaging 10 to 30 minutes, total costs for TKR have increased (Sezer et al., 2021).

In relation to increased total costs and not delivering enough improved outcomes, Beal et al. (2016) come to a similar conclusion. Based on a literature review, the authors have tried to find out what role robots play today in TKRs, especially in the alignment of the implant, and what added value can be generated by them. They explain that while cost-effective digital navigation tools are available on the market, they may well reduce the number of outliers in TKRs. However, this is countered by two criticisms. One criticism is that longer operation times lead to additional costs due to additional preparations and increased effort, canceling out any cost savings from new tools. The other is that patient satisfaction cannot verifiably be significantly improved by the more precise interventions achieved with Robotics (Beal et al., 2016).

Another study by Burn et al. (2020) specifically sought to determine the economic cost-benefit of computer- and robot-assisted TKRs and came to a similar result. Using a model, the authors determined threshold prices for TKRs at which surgeries would still be worthwhile when measured by one additional QALY. Based on these thresholds, statements can be made about the added value that robotic systems must offer the patient in order to be used instead of a conventional knee replacement procedure. An example given was the reduction of the risk that early revisions becoming necessary due to postponements. Another given was a clearly recognizable improvement in patient-reported outcomes. Only then, they surmised, can the currently high prices for robot-assisted interventions be justified (Burn et al., 2020).

Two studies were less critical and more focused on PROMs, coming to different conclusions. Based on 154 TKRs, Bollars et al. (2020) investigated how many outliers occur when using an image-free handheld robotic system compared to conventional methods. Both groups consisted of 77 patients. The analysis showed that the test group which operated with the robotic assistance produced significantly fewer outliers, five compared to 14 from the control group. Still, the authors suggest that the clinical relevance of the results needs to be questioned and confirmed in long-term studies (Bollars et al., 2020). Similarly, Zhang et al. (2016) compared the accuracy of computer-assisted positioning of knee prothesis with established alignment methods. It was found in a test group of 36 patients that robots tended to produce more precise results. Although more time was needed for the procedure, the method was considered simpler in application for surgeons and with less risk of infection for patients (Zhang et al., 2016).

Interview Results

Within the course of two weeks, a total of 27 SSIs were conducted with the following six key stakeholder groups: patients, surgeons, physiotherapists, industry professionals, insurance representatives and regulators. In the weeks prior, a total of 54 potential candidates were contacted via email or phone, whereas six declined and 20 did not respond after at least one reminder as illustrated in Table 1 below. The interviews via preferred virtual communication tool (25 interviewees) or in-person (two interviewees) took on average 29:04 minutes.

Table 1: Semi-structured interview results overview

Group	# Contacted	# Accepted	# Declined	# No reply
Patients	4	4	0	0
Surgeons	20	4	2	14
Physiotherapists	5	3	0	2
Industry	14	10	2	2
Insurance reps.	6	4	1	1
Regulators	3	2	1	1
Total	54	27	6	20

The seven interview questions are outlined in Appendix C. Two force-choice questions with two follow-up questions and three open-ended questions were discussed with each interviewee. The results indicate that the five DTs from the SLR, which are 3D Printing, Big Data, Wearables, Virtual Healthcare and Robotics share a distributed awareness among all stakeholders with only one alternative DT. Big Data followed by 3D Printing and Wearables were concluded to establish promising benefits that affect multiple stakeholders when looking into the future. The answers pointed out that value implications were to be expected while unitedly agreeing that better patient-outcome was at the top of them. To reap the benefits of these DTs, a multifold of challenges with most prominently cost implications and regulatory hurdles are considered to be necessary to overcome.

Question Results

The following sections elaborate the response within the key stakeholder groups as outlined in Appendix B.

1. **Which of the following Digital Technologies within the patient journey of TKA do you consider to be relevant today?**

Patients: With the most overlaps in DT clusters, three (P1, P3 and P4) out of the four patients were aware of 3D Printing technologies in relation to TKA either offered by their selected surgeon or via their own research. Two (P1 and P4) mentioned that their willingness to use this 3D technology was strongly dependent on their trusted surgeons' proposal. Other DT clusters were merely selected or even unknown, such as Wearables, where one patient (P2) said that at her age this would be overwhelming and pose difficulties of interpretation.

Surgeons: All surgeons interviewed (P5 - P8) see Robotics as an already highly relevant part of joint replacements. Two of them (P6 and P7) use navigation or assisting robots in their TKA surgeries. Three (P5, P6 and P8) out of the four surgeons see 3D Printing technologies, either for implants or for PSI, as already established and helpful in TKAs. Also, Big Data is seen as very important by the same three surgeons even though there is still much work to do to leverage all the data which was collected over decades, often in analogue format. All the surgeons expressed the opinion that 3D Printing, Big Data and Robotics are highly dependent on each other and interconnected while the success of one improves the progress of the others. Three interviewees (P6 - P8) reported that Virtual Healthcare plays a role for them today but consider that the potential could be much higher than what is available on the market. Wearables in combination with TKAs are not widely used yet but still important according to two surgeons (P7 and P8). Technology will become more relevant as new tech-savvy generations of patients arrive. One surgeon (P5) spoke of another DT, Deep Learning Diagnostics, which he did not find in the DTs in question.

Physiotherapists: Two (P9 and P10) out of the three interviewees consider that Big Data is already used in the TKA journey. Especially registries with data from clinics help to give new insights according to P9. All three physiotherapists (P9 - P11) said that Wearables have a relevance today already. They value the possibility to have quantifiable data like step count which goes beyond the subjective descriptions such as pain level of the patients. Nevertheless, there is still great potential to popularize the technology. All interviewees (P9 - P11) use Virtual Healthcare as a supporting tool in their routine work. Examples cited included exercise instruction via video, informative apps, and telephone counseling.

Insurance representatives: All four interviewees (P14 - P17) see a relevance in all five DT trend clusters. One (P16) saw an additional relevance in AI while another (P14) expressed the opinion that developing a "digital visible patient journey" in combination with mHealth should also be placed separately to the existing DT trends. Big Data was rated as strongly important (P14, P16, P17) in terms of comparing outcome measures for process optimization reasons. One insurance interviewee (P15) said that only the field of Robotics, specifically during physiotherapeutic rehabilitation, is relevant today. By highlighting an example of scheduling a doctor's appointment, P15 pointed out that integrated digital platforms are not yet the reality.

Regulators: Both regulators (P12 and P13) see relevancies in several fields and stated that Virtual Healthcare is very important in current times and heavily discussed in regulation settings. While P12 stressed that one advantage with this technology is to deliver more customized and supportive care, P13 mentioned that depending on their risk classification, remote technologies remain highly regulated.

3D Printing was perceived by them to have a lower importance due to its maturity stage and currently low production volumes. While Wearables were described by them as an effective means for early detection and rehabilitation monitoring, they emphasized that the intention of usage specifically for medical purposes was a key for defining their classification and field of utilization. As for Big Data, it was mentioned by P13 that arthroplasty registries, such as prominent ones from Sweden, are gaining increased importance and attention.

Industry: Six out of ten industry stakeholders (P18, P19, P22, P20, P25 and P26) see 3D Printing to be a relevant trend today. The key advantage pointed out by these stakeholders was the fact that compromises about the size of the implant or instrumentation do not have to be made. On the other hand, stakeholders who did not consider it to be relevant pointed out that the price-benefit relation of this technology is still a limiting factor. Big Data was considered relevant by seven out of ten stakeholders (P18 - P23 and P25). This trend was considered to be a huge aspect in the TKA journey, with data availability being well advanced, but what to do with the data and how to connect the dots is still an open evolving question. Generated health data was said to allow surgeons to learn and make objective decisions based on other TKA procedures. This results in more predictive and less reactive decision making. Stakeholders who did not consider Big Data to be relevant emphasized that it is still very new, no one really knows what to do with it or that only small data is available (P24, P26 and P27). The relevance of Wearables was acknowledged by half of the interviewees (P19, P20 and P24 - P26) as a mean to generate data and also to be directly related to virtual healthcare. P27 pointed out that Wearables can be complex for less technology driven people and thereby a limiting factor for this DT. Virtual Healthcare is relevant today for six stakeholders (P18 - P20, P23, P25 and P26). P18 pointed out that this trend was accelerated by COVID-19 with clinical follow-ups being done remotely and still having good outcomes. Robotics was described by all stakeholders as a relevant trend, except for P27 who did not see a significant relevance in any of the trends presented. P18 claimed that the significance of Robotics increased in the last 12 to 18 months due to new players and products being launched in the market, an aspect that can increase awareness and lobbying about the technology. Stakeholders P18, P23 and P25 additionally pointed out that the interconnectivity of these technologies and the exchange of data in an omnichannel is what will generate value-based and patient-centric healthcare.

Overall stakeholder representation of question 1

The interviews revealed that all identified DTs were almost equally selected while only a small portion mentioned other DTs. Table 2 shows how often each DT was selected by the individual interviewees.

Table 2: *Stakeholder group summary to question 1*

Cluster	#of selections
A. 3D Printing	14
B. Big Data	17
C. Wearables	13
D. Virtual Healthcare	16
E. Robotics	18
F. Other	5

2. **Which of the following Digital Technologies within the patient journey of TKA do you consider to be the most relevant and promising in the future?**

Patients: In line with the most selected DT in questions 1, three patients (P1, P3 and P4) also stated that 3D Printing technologies will gain influence as it could provide a more individualized and customized implant experience. P4 specifically thinks to the best of his knowledge that this is the most convincing DT as it can tailor the customized implant with one's unique anatomy.

Surgeons: Two surgeons (P6 and P7) chose Big Data as the most influential DT. The extensive use of data will improve the handling of the patients in possibly all process steps from pre-operative to post-operative. P5 considers Robotics to become even more relevant in the future with the technological advancements to come. Nevertheless, the interviewee is confident that surgeons will never be completely replaced by robots, comparing surgeons to airplane pilots.

Physiotherapists: Among the physiotherapists there was no uniform view on the most promising technology in the future. P9 thinks that Big Data will enable HCPs to optimize processes and improve decision making and hence will have a major impact on the TKA journey. P10 foresees Wearables as the most relevant DT as the devices can accelerate rehabilitation via feedback-systems and home workout. Lastly, P11 conceives Virtual Healthcare to be the technology which has the greatest potential to be broadly established with a positive effect on HCP and facility capacity utilization.

Insurance representatives: Three (P14 P16 and P17) out of the four insurance interviewees selected 3D Printing as the most promising future DT for patients. For example, similarities of the benefits of individualization were compared to customized teeth implants by P14. P16 estimated that the need for revisions would decrease, thereby extending the lifecycle of the TKA. P16 believes that while the other DTs are already heavily discussed in pharma settings as well, 3D Printing is considered as a niche field with promising patient benefits. P15 considered Big Data would heavily support key stakeholders to make better objective decisions. The interviewee gave as an example, the perfect or most optimal intervention time which could be a valuable outcome when relying on Big Data as part of DT.

Regulators: From the answers received, regulator P12 believes that the exploitation of wearable technologies could provide the most promising benefit to patients by driving a more active engagement and promoting accountability over their respective health journey.

Industry: All Industry stakeholders except for P22, P24 and P25 selected Big Data as the most relevant technological trend for the future. It was pointed out by P18 that Big Data can only be generated if there is a tool to collect it, meaning that Big Data generation is the ultimate result of the development of the other alternatives. According to P18 and P20, stakeholders are getting closer to understand how the collected data will be used and the acknowledgments leveraged throughout the entire TKA journey. The ability to become more consistent, predictive, transparent and to be able to compare, were aspects of Big Data mentioned by P19, P21 and P26. According to P27, data is the fundamental need and will help all stakeholders to compare, decide and as stated by P26, achieve the ultimate goal which is to deliver better outcomes. Between stakeholders who did not select Big Data as the most promising future trend, P22 sees 3D Printing as a premium solution which at the same time has the potential of optimizing production logistics and reduce waste. P24 sees Virtual Healthcare as the strongest future trend and mentions that it is already a very strong trend in the United States. Stakeholder P25 stated that all trends have their individual value, and the future lies in a connected platform making the best use of all technologies to improve value creation.

Overall stakeholder representation of question 2

The interviews revealed that Big Data was mentioned by 41% of all participants as the most promising DT in the future. Table 3 shows how often each DT was selected by the individual interviewees.

Table 3: *Stakeholder group summary to question 2*

Cluster	#of selections	% of total selections
A. 3D Printing	7	26%
B. Big Data	11	41%
C. Wearables	3	11%
D. Virtual Healthcare	1	4%
E. Robotics	1	4%
F. Other / None	4	15%

3. What is the value created by Digital Technologies to you or by you as a key stakeholder?

Patients: The interviewed patient group (P1 - P4) listed several estimated benefits such as supporting one's motivation during pre- and post-operative stage, accelerating rehabilitation time, enabling the healthcare provider to illustrate to them more realistic benefits of the TKA, improving the overall patient journey experience and, lastly, developing a better communication network with all key stakeholders.

Surgeons: For two surgeons (P7 and P8) the clear purpose for technological advancements should be an improvement of PROMs. At present, it is difficult to prove benefits because of the lack of long-term studies. Nevertheless, technological tools can already be used, although at a higher cost, to facilitate the work of HCPs. P5 described the added value in the surgery room. Higher sterility, more precision and less errors will enable the surgeons to deliver higher quality in less time. Moreover, the ability to monitor patients after the surgery via sensors and Wearables helps to reduce the risk of revisions or needing to intervene early. In addition to those responses, P6 does not believe that conventional methods and processes can be optimized any further without resorting to technological innovations. New solutions are needed to meet demand and manage more operations per year while reducing the average revision rate.

Physiotherapists: All three respondents (P9 – P11) see the main benefit of DTs in creating valuable data which can be analyzed and ultimately help the patients. Extensive amounts of data add a new layer to therapies as they create transparency and allow objective decision making. P11 pointed out that due to limited resources and personnel shortage, Virtual Healthcare combined with patient data enables physiotherapists to respond better to the needs of patients and increase the quality of treatments.

Insurance representatives: Optimal service at minimal costs was at the center of all the respondents' answers. P16 emphasized that apart from the one dimension being better patient treatment, the other dimension of cheaper and more affordable methods should result from the implementation of DTs. P14 and P16 both argued that paying for innovation is only reasonable when clear value adding improvements are made of both dimensions. In the long-term, the value to insurers will be cost reductions while increasing their reach for healthcare treatment. P15 took a more holistic approach and stated that the ultimate goal is to keep people healthy and ensure a high quality of life. Therefore, P15 pointed out that it is crucial to keep the healthcare system affordable for everyone as well as keeping a close eye on monetary developments. P14 mentioned that insurance organizations strive to grow closer to the patient as a trusted "health partner" and want to break away from the "payer" role. DTs could thereby enable higher engagement throughout the patient journey.

Regulators: P12 mentioned that from a regulatory perspective, a key interest lies in data management with research and surveillance purposes, thus helping to guarantee safer implants and medical devices. This data, as long as it is determined to be of high quality, can be then used for research and industry settings to develop improved medical devices and thereby deliver a better healthcare outcome. Building on this perspective, P13 pointed to the currently non-operational European Database on Medical Devices (EUDAMED) which aims to provide a lifecycle picture to enhance overall transparency of medical devices. This is necessary to deliver the essential regulatory function across member states. Efficiency gains such as cost reduction, faster procedures and less errors were a potential value for stakeholders P19, P22 - P23, P26 and P27.

Industry: For P18 - P20 and P24 - P26 the value created by DTs is a better outcome for the patient. This can be achieved with the data generated, which can help to quantify and understand what satisfaction actually means in order to react and make the correct decisions. Furthermore, as pointed out by P24 and P25, individualization and a more patient-centric approach can also result in better outcomes. The point of technology improving the quality of decisions made was brought up by P18, P19, P22 and P24. Decisions can be made more objectively and predictively instead of reactively. Some decisions which are currently more of a skill without technology and data support will become more science-based in the future, DTs have the potential to reduce the "rule of thumb" and the variance. Working more efficiently and improving processes like training, communication, data management and automatizing trivial work was mentioned by seven out of 10 stakeholders (P19 - P23, P26 and P27). Finally, as pointed out by P25 and P26, DTs will allow attendance to unmet needs which for the patient will result in a better experience and for the industry has the potential to develop new revenue streams.

Overall stakeholder representation of question 3

The interviews revealed seven categories of value adding perceptions. Throughout the stakeholder groups, patient-outcome improvements as well as process and operational excellence were the most prominent ones.

Table 4: *Stakeholder group summary to question 3*

Value added	Patients	Surgeons	Physio-therapists	Insurance Reps.	Industry	Regula tors
(1) Improve patient outcomes	×	×	×	×	×	×
(2) Process and operational excellence		×		×	×	×
(3) Quality of decision-making		×	×		×	
(4) Advance transparency	×			×		×
(5) Fulfill unmet needs			×		×	
(6) Support motivation and behavior	×		×			
(7) Develop better communication	×					

4. How do you think Digital Technologies may have an influence on your key stakeholder role within the TKA journey?

Patients: The responses received to this question were manifold. P1 argued that several factors such as the influence of his family, health condition, age, pain level and his trusted surgeon's opinion all formed his decision when to undergo his elective surgery. He could imagine that DT in some form could support patients to compute perfect time of intervention. P3 and P4 stated that they felt that patients would thereby gain more responsibility in future for their own health journey by gathering health information from forums and data banks which in turn would enable them to be more engaged in the decision-making process. P4, on the other hand, cautiously pointed out that too much information could impede and complexify the decision-making process.

Surgeons: The surgeons interviewed (P5 – P8) predict that their jobs and responsibilities will, in general, stay the same. P6 called DTs "just another tool" to help do the job in the best way possible. They must be useful to a surgeon's two key tasks which are operating and being in a dialogue with the patients. Nevertheless, they commented that "bad surgeons will not become good surgeons thanks to technology". Regarding stakeholder relevance among HCPs, P5 supposes that certain fields will become more relevant than others. For example, the capabilities of doing 3D scans will make radiologists even more involved along the TKA journey. According to P7, decision making of surgeons about treatments or surgeries will probably be significantly influenced by Big Data and AI in the near future. All the generated and collected data will also bring more transparency regarding the quality of a surgeon's work which can result in performance pressure.
Physiotherapists: P10 and P11 expect a great impact on how physiotherapists will work in the future. This also requires them to learn new digital skills and invest in technology. The latter will involve major changes, especially for independent physiotherapists, as investment costs are high and the relationship with patients will change. P10 sees the profession shift to more a motivational coaching function than a treatment function. Interviewees P10 and P11 share the concern that patient relationships may be limited by DTs because personal bonds are harder to form in the digital space. P9 does not feel like DT will fundamentally change the profession of physiotherapists. However, new technologies will add another layer of complexity when it comes to misinformation among patients and the well-founded scientific correction by HCPs.

Insurance representatives: While one interviewee P15 saw no direct impact on their role, the others mentioned that they will have to transform to provide easier and flawless processes to their customers. P14, for example, assumes that a restructuring of claim management will be necessary to move away from analogue and manual systems. This service can thereby be drastically improved yielding less time and hassles for their customers. P16 further estimates that DTs, such as telemedicine, will continue to free up the resources of their stakeholders and thereby become a key part of insurances. P17 remarks that innovative DT solutions which are at a lower maturity level could be used if combined with a supplementary insurance. This temporary solution could hereby be waiting in place until it is widely acknowledged by the Bundesamt für Gesundheit (BAG).

Regulators: P12 emphasizes that DTs will increase their responsibility to provide high quality secondary data to support the future of data-driven solutions. P13 mentions that such data outputs will be taken into consideration after evaluation in terms of their impact on regulatory frameworks. One of the goals hereby is to create value by empowering others such as the industry to create better solutions. With an inside view, P12 estimated that new jobs and skills will be necessary to integrate DT in a regulatory setting.

Industry: P18, P20, P21 and P26 pointed to a mindset change where the focus of the industry becomes patient-centric. The efforts, the selling proposition and the goodwill lie in the improved outcome of the patient throughout the entire episode of care. Three Stakeholders (P18 - P20) emphasize the possibility to work more efficiently by, for example, having remote trainings and avoiding travel expenses. This could release resources to reinvest in technology and new digital solutions. Four (P18, P24, P26 and P27) out of 10 stakeholders see changes or transfer in their function, decision making or responsibility. P18 argued that when giving recommendations, you take part of the responsibility for the results. P24 pointed out that the role of the technician will be changed by him/her being often remotely available as a consultant instead of a direct supporter. P26 felt that his company will become partially a data organization instead of a metal and plastic manufacturer. P27 commented that the scope of technical roles will be increased. For P20, P22 and P25 their role will be impacted by changes in communication, understanding and feedback. Communication will be remote and accelerated and it will help to better understand the mindset of the customer by using feedback. This acceleration will also require an improved change management. Finally, P22, P23 and P25 pointed to changes in business practices and business models, where the development of the software not only gains relevance, it also consumes resources to increase the focus in digital therapeutics.

Overall stakeholder representation of question 4

The interviews revealed seven categories of influence factors introduced by DTs. Throughout the stakeholder groups, the factors were almost evenly distributed with the industry being the only stakeholder acknowledging all represented factors.

Table 5: *Stakeholder group summary to question 4*

Influence factors	Patients	Surgeons	Physio-therapists	Insurance Reps.	Industry	Regulators
(1) Require different job skillset and competencies		×	×		×	
(2) Efficiency gains		×		×	×	
(3) Changes function, decision-making and responsibility	×				×	×

(4) Changes in communication			×	×
(5) Changes in business practices and business models		×		×
(6) Shift in relevance	×			×
(7) Drive patient-centric mindset				×

5. Why do think these Digital Technologies are not yet broadly established?

Patients: Two patients (P1 and P4) talked about the need to break down complex technological insights in a comprehensive manner. This comment was also connected to the statements received in question 4 about the large amounts of information flow. P3 stated that the type of surgeons, often viewed as "hands-on" experts, will be critical for the buy-in of DTs while some will remain resistant towards innovative DTs. It was pointed out that this could also be linked to a generation aspect. P1 mentioned that time to maturity of DTs, financial strength of clinics and new questions in terms of liability may be reasons for a prolonged implementation of these technologies.

Surgeons: The interviewees P6 and P7 noted that one important factor which prevents DTs from being rolled out on a broader basis is time. On the one hand, introducing new tools and processes always requires surgeons who already have tight schedules to invest a lot of time to learn new skills and adapt to the changes. On the other hand, the implementation of medical devices or medical software takes very long, and the new technology might already be outdated once it fully goes live. Three surgeons (P5, P6 and P8) suggested that DTs involve high initial investments and running costs which often times are not seen by them as justified. Reasons are the lack of clear evidence that the new technologies improve patient-related outcomes or a common mindset that the TKA journey is efficient enough with today's methods and processes. P5, P7 and P8 also mentioned regulations, certifications, and complicated approval procedures as restraining factors. In terms of medical infrastructure, P5 believes that there are too many hospitals that offer an excessive range of services. Specialized hospitals could invest more easily and drive the expansion of DTs. P6 feels that the lack of trust in technology also leads to a slowdown in innovation.

Physiotherapists: Regulations and high investment costs are addressed by all the interviewees (P9 – P11) as the main reasons why DTs are not yet used to its full potential. The physiotherapists are also very dependent on how they get reimbursed by the insurers for their services. In many cases, treatment with digital aids is not worthwhile because less money can be billed. One example is the telecommunication and online consultation hours which today generate 2.5 times less fees than physical in-person treatments. P10 thinks that there are hurdles when it comes to implementing evidence from science in a practical environment, that if DT finds practical application, 10-15 years may pass in between.

Insurance representatives: P14 and P16 both believe that data privacy plays a key role in why DTs are not yet widely accepted. While Wearables are seen as a great means to motivate patients and are also supported by insurances, they create a suspicion on what insurances do with such intimate data. In support of this, P16 compared what people preferred to have laid out in public, one's bank statement or one's medical history. One is a temporary snapshot while the other can impede getting a job by allowing groundless interpretation. P15 stated that the wide landscape of industry competition in the field of DT requires intense amount of capital with correspondingly high expectations. The dependence on regulation settings and decisions by the BAG is a factor which P17 thought to be responsible for why certain applications are allowed to be covered by the mandatory or supplementary insurance.

Regulators: A multitude of reasons were mentioned by both interviewees (P12 and P13) such as high investments required, liability allocation and little clinical evidence. Other reasons given were the challenge of deriving valuable insights from data, lack of testing of DTs and challenges for the industry to adhere to a comprehensive level of reporting. One regulator (P13) mentioned that the acceptance of data from electronic sources is not yet homogenous across member states, making comparability difficult. For data in particular, the scope is covered by specific data privacy regulations and not by medical device regulations.

Industry: Resistance to change or skepticism towards the benefits was a common point raised by P18, P19, P22, P26 and P27. As stated by some of the interviewees, HCPs are used to work in a certain way. TKA is a procedure with already good outcomes due in great part to the physician's ability and experience. HCPs can only be convinced to change if the benefits are clear and the technology is mature enough. The amount of information was also a point raised. Suddenly, a lot of new information is provided to the surgeon who is not sure how to manage it. P18, P19 and P21 pointed to technical hurdles when it comes to training, the maturity of the technological advancements and the adjustment of quality systems to technology instead of only metal and polymer. Half of the industry stakeholders (P19, P21, P22, P24 and P25) emphasized data issues like privacy, management, security, complexity and right to use. What is done with the data, how to ensure secure storage and who can access it were some topics raised. P20 and P26 mentioned that the complexity and amount of information available can be overwhelming and potentially override the benefits. Compensation, legal and policy hurdles is an aspect cited by P21, P22, P24 and P25. Compensation is still very complex and does not always cover DTs. It is often not clear what is legally allowed in the operation room and who carries the responsibility and for this to change, conversation with the policy maker needs to increase. Finally, according to P19, P22, P23 and P27, the positive cost-benefit relation is not clear to all the players yet. Firstly, the financial and time investment to develop or acquire technology is very high and, secondly, the benefits are not always that obvious and need time to be shown.

Overall stakeholder representation of question 5

The interviews revealed nine categories challenging the establishment of DTs. Throughout the stakeholder groups, regulatory hurdles and unclear cost-benefit relation were most prominently named. As with question 4, the industry is the only stakeholder acknowledging all represented challenges.

Table 6: *Stakeholder group summary to question 5*

Challenges	Patients	Surgeons	Physio-therapists	Insurance Reps.	Industry	Regulators
(1) Regulatory hurdles	×	×	×	×	×	×
(2) Unclear cost-benefit relation	×	×	×	×	×	×
(3) Not enough evidence		×	×		×	×
(4) Data Privacy concerns			×	×	×	×
(5) Time - maturity level	×	×	×		×	
(6) Resistance to change	×	×			×	
(7) Complexity of the information	×				×	
(8) Reimbursemen t			×		×	
(9) Technical hurdles					×	×

Discussion

The initial assumption driving the approach adopted for this paper was that research generally reflects the needs of the stakeholders. A higher quantity of research about a certain topic can indicate an increased interest on the part of the stakeholders. The possible caution here is, however, that research can also anticipate market needs and explore opportunities. It is also possible that, although a topic can be widely discussed in the healthcare industry, it may not be driving scientific research. In this case, literature about the topic may be limited. To study DTs comprehensively, it is important to consider the literature while also confirming the findings with stakeholders who have influence and touchpoints within the TKA patient journey.

Revealing today's relevance of Digital Technologies along the TKA journey

All the DTs were mentioned by approximately half of the respondents for question 1 (Appendix C). This indicates a relatively equal distribution of awareness throughout the fields. From 27 interviewees within six stakeholder groups, Robotics was mentioned the most by 67% of the respondents, whereas Wearables was mentioned the least by 48%. The almost even distribution across the types of DTs prevents determining a single one as the most relevant trend today. As less than 20% selected option F (none of them / other) in question 1, the five clusters defined based on the SLR can be considered to be a fair representation of the relevant DTs today in TKA. Furthermore, when option F was chosen, in almost all cases the additional DT trend mentioned could be subcategorized under the predefined DT clusters. AI was the only additional trend mentioned which is extensive enough to be potentially considered as a separate DT cluster. Overall, no alternative DT was mentioned more than once in answer F.

The interconnection between the DTs was a recurring point described in the articles of the SLR and was raised by the interviewees in the SSIs. As an enabler of the interconnections, Big Data can be considered as a central hub for health technology. It leverages health information from VHTs and 3D Printing solutions by means of Wearables or Robotics. At the same time, it provides data for these technologies to fully exploit their potential.

Interconnection is an important conclusion of this research. It is also a central part of the industrial revolution 4.0 as pointed out by Klaus Schwab, founder of the World Economic Forum. He states that there will be a blurring across the physical, digital, and biological worlds (Schwab, 2015). In the TKA journey it is no different. As technology becomes more readily available, increasing interconnection will generate the largest benefit for all stakeholders. To rely on one single technology will not suffice and stakeholders acknowledging a digital ecosystem will be at the forefront.

One surprising aspect about question 1 was the low number of alternative selections mentioned by the patient group. In a value-based healthcare system, the patients need to be in the center. For this to occur, they need to be informed about possibilities and developments in their journey. Based on the responses, the information that the patients take with them seemed to be limited. Improved information flow for and between each individual stakeholder throughout the journey can facilitate the transition to a digital ecosystem. Some surgeons are convinced of the actual benefits of these DTs, while others are rather skeptical and point out that some DTs are not mature enough. This skepticism correlates with the literature where no consensus could be found about improved outcomes, but the potential of DTs is widely acknowledged.

With respect to regulators, the respondents did not mention Big Data as such to be a relevant DT, neither today nor in the future. This is understandable since data alone is not a medical device and topics such as data usage and privacy are governed by holistic data privacy laws and not by the medical device regulations.

Physiotherapists most notably recognized Big Data, Wearables and Virtual Healthcare which are the DTs primary found in the pre- and post-operative phase. DTs such as 3D Printing and Robotics were not identified most likely because they are mainly applied in the operating room. The responses by insurers were diverse with no recognizable pattern. The impression is that depending on the insurance company the topic has a different grade of relevance and priority.

The findings of the SLR and the SSIs provided a conclusive answer to RQ1 about which digital trends are relevant in the TKA journey today. The literature shows that 3D Printing, Big Data, Wearables, Virtual Healthcare and Robotics are all presently relevant.

Big Data as the most promising Digital Technology along the TKA journey in the future

When it comes to selecting the most promising DT for the future, 41% selected Big Data followed by 3D Printing (26%) and Wearables (11%). This reflects the interconnection between the DTs with data being at the core, as pointed out by many stakeholders. Big Data will give a boost to predictive medicine, helping to discover patterns and improve decision making.

As discussed by Strauß (2018), there are overlaps between Big Data and AI, which particularly involve the field of machine learning. In its simplest form, AI requires immense amounts of data to collect, analyze, de- and re-contextualize large data sets to explore and recognize patterns (Strauß, 2018). The majority of industry stakeholders as well as surgeons chose Big Data as the central DT of the future. On the other hand, none of the patients selected this DT. This could be an indicator that Big Data as such is a known expression, but the exact meaning and potential seem unclear for the patient. Once again, this reveals a possible communication gap that is to be covered between industry, HCPs and patients.

3D Printing is a second significant DT acknowledged by many stakeholders and selected by all the patients who provided an answer. It was also frequently cited by the insurance representatives as the relevant future DT. Without questioning the benefits of this technology, there could be an attractiveness factor of 3D Printing influencing these stakeholders to pick this particular trend for its personalization opportunities. 3D Printing is being widely applied in different industries when it comes to complex geometries. Within the MedTech industry, 3D Printing enables customization of an individuals' unique and complex anatomy. Nevertheless, the long-term benefits, like implant survivorship, are still unknown and its long-term potential is yet to be revealed (Beal et al., 2016). This absence of long-term evidence combined with cost implications as well as the low production volumes could be one reason why this trend was barely selected by surgeons and stakeholders of the industry.

Wearables come in third place and were mentioned sporadically. Perhaps because Wearables as a standalone DT cannot provide its full potential, if not supported by Big Data or VHTs.

In answer to RQ2, what is the most promising digital trend within the TKA for the future, the majority of the interviewees revealed that Big Data is the most promising DT in the future.

Revealing value perception across stakeholders

One aspect that this paper explored is the value that DTs generate for the stakeholders involved. The literature reviewed provides indications about the added value, although researchers struggle to concur on significant evidence-based statements. On one hand, long-term studies are lacking due to the topicality of the issue. On the other hand, the rather marginal identifiable added value is mostly disproportionate to the additional costs and expenses incurred. Based on the reviewed studies, high-level area of use and value added were identified for comparison of the five DTs in question as listed in Table 7.

Table 7: *Digital Technology area of use and value added*

Cluster	Categories	Area of Use	Value Added
3D Printing	• Patient-specific instruments • 3D models • Patient specific knee prosthesis	• Customized cutting blocks for proper component positioning • Pre-operative surgical simulation and validation • Customized implant	• Customization and individualization • Planning and operations time reduction • Cost reduction • Efficiencies in supply chain

Cluster	Categories	Area of Use	Value Added
Big Data	• Electronic health records • Healthcare registries • Machine Learning • Procedure data • Implant-specific data	• Outcome predictions • Early recognition of complications • Customized and automated patient care • Waiting list Management	• Innovative medical insights • Better decision making • Improvement of predictive diagnostics • Optimized inventory management • Cost reduction • Greater product safety
Wearables	• Smart watches • Smart glasses • Wristband sensors • E-textile • Health monitors • Augmented Reality	• Behavioral activity tracking • 3D movement tracking • Augmented Reality as a training tool • Measurement of sedentary and light activities	• Minimization of human resources • Personalized physical activeness • Patient empowerment and engagement • Data-driven intervention
Virtual Healthcare	• E-Forms • Remote patient monitoring • Virtual Reality • Telemedicine • mHealth • Website deliveries	• Remote patient guidance and monitoring • Early detection of emerging complications • Triaging and delivering patient reminders • Pain control and correlated opiate usage	• Driving patient education • Driving personalized healthcare • Cost saving • Optimized processes • Pain control improvement
Robotics	• Autonomous • Semiautonomous • Passive	• Navigation assistance • Implant positioning and alignment • Positioning for bone resection • Tool positioning	• Quality improvement • Predictable surgical experience • Reduction of errors • Lower rate of readmission • High sterility • Better planning

If this result is compared with the perspectives of the stakeholders from the interviews, a clear discrepancy appears. The single added value which was cited by interviewees across all stakeholder groups is improved patient outcomes as seen in Table 4 in section 0. It appears that there is a difference between the perceived and the scientifically demonstrable value of DTs. Stakeholders along the TKA journey have a rather positive opinion about DTs and their influence on the patients' wellbeing. For the insurances as payers, however, it is mainly clinical evidence which is ultimately relevant. For this reason, subjective opinions and isolated trends have so far not been particularly influential in accelerating the use of DTs.

In addition to improved patient outcomes, certain stakeholders in the interviews have also been able to identify benefits of DTs which, if they help the patient at all, then do so indirectly. Many of those benefits mentioned are consistent with the findings from the SLR. One of them is process and operational excellence which is highly valued by surgeons, insurances, the industry, and regulators. Streamlining processes not only increases efficiency and thus decreases cost, but also allows seamless interactions between patients and stakeholders along their journey, thereby possibly having a positive effect on satisfaction level. Another advantage seen by surgeons, physiotherapists and the industry is improved decision-making. For HCPs it is highly important to make the right decisions when it concerns a patient's life and health. Wrong decisions can have a major impact and lead to serious consequences. Therefore, tools and data that support health history and recommend treatment options along the journey can strengthen confidence and eventually lead to better outcomes with a lower error rate. An interesting element raised by patients, insurers and regulators that has not been specifically addressed in the literature is the increased transparency enabled by DTs. It is not only decision-making processes that have the prospect of being more transparent through digital networking. The quality of implants and other components, as well as the delivery of services, could also be better controlled and ensured. HCPs and industry experts did not cite transparency as a benefit, which may suggest that too much transparency also puts a degree of pressure on the mentioned stakeholder groups. It allows for example to document every step of a process, being exposed to control and audits by third parties.

Another point raised by the physiotherapists as well as the industry was that DTs serve unmet needs. It is notable that none of the other stakeholder groups pointed out this benefit nor was it mentioned in the literature. This suggests that many stakeholders in the TKA journey consider that they are not missing any factors or processes worth noting and are therefore reasonably content with the current situation. The industry serves as a driving force in identifying areas of unmet needs and serving them through innovation. This includes the task of convincing stakeholders of the added value of the solutions they offer and getting these widely adopted. Lastly, patients see improved communication as another advantage of new DTs. This aspect was frequently discussed in the SLR, but not mentioned by the stakeholders interviewed. It is thought-provoking that a key component of the patient journey, namely open and proactive communication and education has been forgotten by many. Data and digital channels such as apps are emerging to offer a new level of opportunities to guide patients through a TKA. Patients who are increasingly shifting to being at the center of their TKA journey are demanding such inclusion.

In answer to RQ3, what value do these technologies generate for the key stakeholders, improved patient outcomes, better decision making, improved processes and transparency can be named as the most important value additions by DTs.

Deriving the impact of Digital Technologies on stakeholders

The introduction of DTs not only challenges proven methods but also often requires established processes to be updated and possibly redesigned in the TKA journey. In the SLR no conclusions could be found as to whether and how the roles of individual stakeholders will change as a result of these developments. However, three aspects can be identified that point to some shifts. Firstly, thanks to process automation and intelligent data utilization, HCPs' administrative workload is reduced (van Kasteren et al., 2018). This frees up capacity and allows HCPs to allocate more time to value adding treatments or specializations. Secondly, stakeholders need to adapt their skills and accept as well as integrate the DTs into the way they work (Jacofsky & Allen, 2016). Certainly, for many stakeholders, this means an initial increase in workload together with a sense of uncertainty and ambiguity. Adaption of courses in universities and vocational schools will most likely be needed to acquire new competencies and keep the HCPs involved up to date with the constant technological advances in the area of TKA, including the rehabilitation phase. Thirdly, technology corporations, especially those in software development, are often new players in the healthcare sector, but will increasingly gain influence in this field (Hermes et al., 2020). All of the DTs analyzed require sophisticated software solutions. For established manufacturers to be able to profit from the developments and to continue to shape the MedTech market itself, strategic collaborations with technology corporations are one significant option. If that is not a viable option, specialized talent would need to be recruited from the tech industry to enable the internal transformation from hardware producer to hybrid hardware-software service provider.

The observations from the SLR can be confirmed by the conducted SSIs. Surgeons and physiotherapists see their roles changing to some extent in light of the introduction of new DTs. They require new skillsets and have to undergo additional training. The surgeons interviewed see benefits, particularly in automation and reduced administrative work, allowing them to devote more time to value-creating treatments. In addition, some medical specialties could gain in relevance and become even more involved in the TKA journey. For example, radiology, with all its imaging data and scans, serves as an important basis for many of the DTs. Physiotherapy is assumed to continue to be highly relevant in supporting and accompanying recovery. New possibilities such as video-assisted telemedicine, interactive digital training programs or tracking Wearables will change the way therapists work and interact with patients. Their role may shift to that of a "health coach", moving further away from physical examination and intervention. Patients see themselves as taking more responsibility in decision-making about going for a TKA in the future, basing their input into these decisions on a variety of available data and information. Patient empowerment is an interesting factor that HCPs and insurers need to keep on their radar. If patients are better informed and have more self-confidence, an increase in patient empowerment is more likely. This has the potential outcome of a reduction in unnecessary procedures, replacing them with effective alternative treatments such as targeted therapies. The benefit would be savings in costs as well as a more efficient allocation of valuable resources.

It was voiced that insurance companies will maintain their role as partners with customers on health issues and their payer base. Nevertheless, a number of insurers view themselves as already moving forward to becoming fully digitized companies that can support customers effectively and promptly in any situation. They are automating manual processes and developing the skills and competences framework needed for Virtual Healthcare. The role of regulators is not expected to be significantly affected by DTs, apart from acquiring the digital skills and understanding required to handle data.

What is striking about the results is that the industry foresees a significant change in many areas through the introduction of DTs. Two reasons can be deduced as to why the stakeholders from the industry come to such a conclusion. On one hand, industry as a stakeholder has the most touchpoints with other stakeholders along the TKA journey. A key function is played by sales representatives, who are in direct contact with HCPs and have regular face-to-face exchanges. Because of the approval processes for new products and health economic queries, companies are also in frequent contact with regulators and insurers. Thanks to the many insights they get, companies have a solid understanding of existing processes as well as methods. They can thus assess how their products or those of the competition will bring changes. On the other hand, the industry is driven economically and competitively and constantly on the lookout for improvements and innovations. Caution is advised as stakeholders from the industry can be somewhat biased and overestimate the impact and benefits of their products.

In answer to RQ4, how are these technologies affecting the role of the key stakeholders, a shift in decision-making and responsibility, efficiency gains as well as the need to learn different skills to keep-up with digitalization were voiced as the main factors.

Overcoming obstacles of Digital Technology establishment

While TKA does not necessarily involve life or death decisions, the impact of the procedure and the intervention throughout the recovery phase can strongly influence the patients in terms of quality of life regained. One reason for a slow establishment of DTs is lagging scientific evidence. To accelerate scientific research, data-driven solutions need to be exploited to move towards a combined proactive and reactive care approach. The risk-averse culture in healthcare which has limited time for exploration and experimental settings outside of controlled research environments can influence the integration of DTs. It is particularly important for users of these DTs to be assured that they can be integrated without going through non-efficient and lengthy implementation iterations. Surgeons for example mentioned that the establishment of such technologies would have to provide clear benefits which have been proven to be successful in precedent settings.

Apart from the lagging evidence, this paper has identified three more challenges which were pointed out by several stakeholders: regulatory hurdles, cost-benefit uncertainties and data privacy issues. Across the entire stakeholder base, regulatory hurdles and cost-benefit uncertainties were all named. Regulation plays an important role in healthcare as it is concerned with implementing measures to protect public health and welfare. Legal and compliance standards can either promote or in some cases make it unattractive to apply a certain technology. As an example of the latter, teleconsulting as an alternative of face-to-face coaching sessions is only reasonable if the financial coverage for the HCP and the patient are at a justified level. This was a particular reason why despite existing hardware and software means on the HCP side, this DT is yet to become financially justifiable. If this is achieved, the complete set of benefits such as scalability, reduction of travel time and efficient coaching could be leveraged.

A literature review by Kraus et al. (2021) similarly detected regulatory hurdles as one out of three main concerns and as a reason for the lagging adoption of DTs. This literature review, however, did not address cost-benefit implications as a major obstacle. Other studies like from Higgins et al. (2020) have outlined, that the use of VHTs and Wearables create operational efficiencies for HCPs, such as reduced length of stay and lower readmission rates. The studies however do not go into detail about what short- and long-term capital investments, such as acquisition and maintenance costs, were necessary to achieve efficiency gains. This is one area where the SSIs allowed to include the perspective of HCPs as the owners and in most cases buyers of such DTs. Also, insurance representatives saw that DTs require high capital investments, especially when the technology is not yet broadly established. In the example of hand-held robotic systems, only a few financially strong clinics and hospitals are able to make such capital intense purchases. Here, the key driver was not particularly operational efficiency gains, but moreover a marketing tool to differentiate among clinics. As observed also in question 3 about the value created by DTs, the industry mentioned all of the identified challenges since it shares the most touchpoints with other stakeholders.

Another significant obstacle to the establishment of DTs is data health privacy and its implications. The literature reviewed and respondents in the SSI emphasized that health data, being intimate and sensitive, needs to be protected by regulation and cybersecurity platforms. There is a tradeoff between valuable data insights from joint registries for example, and data privacy concerns. On the one hand, Big Data brings along apparent analytical and predictive benefits, as outlined in earlier sections. On the other hand, there seems to be a concern when sharing health data. Regulators mentioned that specific data privacy laws are in place and continuously evolve to ensure protection and governance.

In response to RQ5, why are these technologies not yet mainstream and broadly established, regulatory hurdles alongside with cost-benefit uncertainties were voiced as the main factors, followed by not enough evidence and data privacy issues.

Limitations and Further Research

Digitalization in healthcare is a vast topic. Even with the decision to focus on the specific TKA procedure, it is unlikely that this research covers all the transformations occurring in this field. The combination of the SLR search terms as well as the structured approach was selected after several experimental iterations. It cannot be ruled out that with another approach further relevant papers would have been found. However, it is not likely that other major DT clusters would have been revealed. With regards to the interpretation of the SLR articles, the judgment of relevance is exposed to a certain level of subjectivity. In order to compensate this, the SSI questions 1 and 2 included the options to mention other DTs. This allowed to complement and challenge the presented interpretations with the experts' opinions. The SSIs had the intent to obtain confirmation of the SLR findings and provide further insights for the research questions. Another limiting factor was that access to stakeholders was not equal. For example, industry stakeholders compared to surgeons were more responsive and agreed more often to be interviewed. Also, patients were difficult to find because of privacy reasons. This led to an uneven sample distribution between the stakeholder groups. Consequently, this could have had an impact on the findings, as the level of knowledge between the stakeholders is different. Homogenizing and increasing the sample size across all stakeholders could provide further valuable insights and a statistical validity to our findings. Further research could also explore the timeframe until the listed DTs become broadly established. Answers to these questions could be provided by focusing on an individual stakeholder group with increased sample size.

Conclusion

Digitalization is a vast topic which is mostly discussed for healthcare as a whole. Most literature about digitalization does not focus on a specific procedure or treatment. The present research used an SLR enriched by SSIs with 27 key stakeholders across six roles to explore how digitalization is affecting the TKA journey. The SLR identified 3D Printing, Big Data, Wearables, Virtual Healthcare and Robotics as the most recurrent DTs within the TKA. In a second step, the stakeholders (patients, surgeons, physiotherapists, industry experts, insurance representatives, regulators) were asked in SSIs to confirm and expand the findings of the SLR.

The findings show that all five DTs are relevant and recognised today. However, there is an anticipated knowledge gap between the different stakeholders. Patients, regulators and physiotherapists acknowledged a few digital trends, whereas surgeons and industry stakeholders recognized the relevancy of all of them. Big Data is considered to be the most promising trend for the future, followed by 3D Printing and Wearables. Improved patient outcomes, better decision-making, streamlined processes and more transparency were pointed out as the most important value additions by DTs. As regards to influences on stakeholders' roles, a shift in decision-making and responsibility, efficiency gains as well as the need to learn different skills to keep-up with digitalization were voiced as the main factors. When questioned as to why these technologies are not yet mainstream, regulatory and data privacy issues, maturity of technology as well as a unclear cost-price benefit relation were cited as recurring barriers. The shift to a patient-centric and value-based healthcare system requires consideration of the entire journey and harness all benefits that technology can provide.

Our findings point out that these technologies can be fully exploited when working in an interconnected ecosystem where data is exchanged unrestrictedly. The coordinator and ultimate decision-maker in this ecosystem remains the surgeon, but the central character is the patient. Not only for the TKA but also for other medical procedures, companies need to recognise and leverage interconnection opportunities in the creation of ecosystems promoted by DTs. The greatest value can be generated from increasing quality of life and pain relief throughout the journey at a reasonable cost, rather than solely focusing on the implant or surgical procedure. Surgeons on the other hand, need to regard technology as an empowering support to perform trivial activities, increase precision, and store and analyse data, thereby allowing them to focus on more complex and specialized challenges. DT development will require HCPs to be prepared for more involvement beyond their field of expertise. It is up to regulators and insurances, often perceived as conservative and static, to be ready to adapt when sufficient evidence points towards the necessity to do so. For the patient, the stakeholder in the centre of this journey, the recommendation is to acknowledge their unique position and take on a more active role. From being informed to remaining actively involved, patients are transitioning from mere passengers to becoming drivers of their own journey.

Overall, this paper has recognized the importance and variety of digital DTs in the context of TKA. The interconnection of the DTs supported by Big Data will help improve patient outcomes. Finally, we believe that the insights presented in this paper can be applied in similar patient journeys beyond the TKA.

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Appendices

Appendix A

Table 8: *Synthesis of key Structured Literature Review*

3D Printing *n = 5*
1. *A high level of satisfaction after bicompartmental individualized knee arthroplasty with patient-specific implants and instruments* (Ogura et al., 2019) 2. *Evolving a Value Chain to an Open Innovation Ecosystem: Cognitive Engagement of Stakeholders in Customizing Medical Implants* (Randhawa et al., 2021) 3. *3D-printing techniques in a medical setting: a systematic literature review* (Tack et al., 2016) 4. *Patient-Specific Instruments Based on Knee Joint Computed Tomography and Full-Length Lower Extremity Radiography in Total Knee Replacement* (Tian et al., 2018) 5. *The Effect of Patient-Specific Instrumentation Incorporating an Extramedullary Tibial Guide on Operative Efficiency for Total Knee Arthroplasty* (Kwon et al., 2017)
Big Data *n = 7*
1. *Demographic Variables Accurately Predict Component Sizing in Primary Total Knee Arthroplasty* (Sershon et al., 2017) 2. *Total Knee Replacement and the Effect of Technology on Cocreation for Improved Outcomes and Delivery: Qualitative Multi-Stakeholder Study* (van Kasteren et al., 2018) 3. *Big Data and Health Economics: Strengths, Weaknesses, Opportunities and Threats* (Collins, 2016) 4. *The Arthroplasty Candidacy Help Engine tool to select candidates for hip and knee replacement surgery: development and economic modelling* (Price et al., 2019) 5. *2D/3D reconstruction of the distal femur using statistical shape models addressing personalized surgical instruments in knee arthroplasty: A feasibility analysis* (Cerveri et al., 2017) 6. *Prospective Validation of a Demographically Based Primary Total Knee Arthroplasty Size Calculator* (Sershon et al., 2019) 7. *Arthroplasty implant registries over the past five decades: Development, current, and future impact* (Malchau et al., 2018)
Wearables *n = 8*
1. *Healthcare professionals' proposed eHealth needs in elective primary fast-track hip and knee arthroplasty journey: A qualitative interview study* (Jansson et al., 2020) 2. *Medium-Term Outcomes of Digital Versus Conventional Home-Based Rehabilitation After Total Knee Arthroplasty: Prospective, Parallel-Group Feasibility Study* (Correia et al., 2019) 3. *Predicting Subjective Recovery from Lower Limb Surgery Using Consumer Wearables* (Karas et al., 2020) 4. *Smartphone App with an Accelerometer Enhances Patients' Physical Activity Following Elective Orthopedic Surgery: A Pilot Study* (Van Dijk-Huisman et al., 2020) 5. *Physical activity after outpatient surgery and enhanced recovery for total knee arthroplasty* (Schotanus et al., 2017) 6. *Can an Augmented Reality Headset Improve Accuracy of Acetabular Cup Orientation in Simulated THA? A Randomized Trial* (Logishetty et al., 2019)

7. *Home-based Rehabilitation With A Novel Digital Biofeedback System versus Conventional In-person Rehabilitation after Total Knee Replacement: a feasibility study (Correia et al., 2018)* 8. *A Community-Based Physical Activity Counselling Program for People With Knee Osteoarthritis: Feasibility and Preliminary Efficacy of the Track-OA Study (Li et al., 2017)*
Virtual Healthcare *n = 10*
1. *Can technology optimise the pre-operative pathway for elective hip and knee replacement surgery: a qualitative study (Haq et al., 2020)* 2. *Comparing an eHealth Program (My Hip Journey) With Standard Care for Total Hip Arthroplasty: Randomized Controlled Trial (Saunders et al., 2021)* 3. *Development of an individualized asynchronous sensor-based telerehabilitation program for patients undergoing total knee replacement: Participatory design (Naeemabadi et al., 2020)* 4. *Sana: A Gamified Rehabilitation Management System for Anterior Cruciate Ligament Reconstruction Recovery (Kungwengwe & Evans, 2020)* 5. *Effectiveness of an Automated Digital Remote Guidance and Telemonitoring Platform on Costs, Readmissions, and Complications After Hip and Knee Arthroplasties (Rosner et al., 2018)* 6. *Technology-assisted rehabilitation following total knee or hip replacement for people with osteoarthritis: a systematic review and meta-analysis (Wang et al., 2019)* 7. *Is virtual clinic follow-up of hip and knee joint replacement acceptable to patients and clinicians? A sequential mixed methods evaluation (Parkes et al., 2019)* 8. *Healthcare professionals' proposed eHealth needs in elective primary fast-track hip and knee arthroplasty journey: A qualitative interview study (Jansson et al., 2019)* 9. *Improving resource utilisation and outcomes after total knee arthroplasty through technology-enabled patient engagement (Higgins et al., 2020)* 10. *Effectiveness of a Mobile eHealth App in Guiding Patients in Pain Control and Opiate Use After Total Knee Replacement: Randomized Controlled Trial (Pronk et al., 2020)*
Robotics *n = 9*
1. *Knee Prosthesis in the Computer Era (Sezer et al., 2021)* 2. *Preliminary experience with an image-free handheld robot for total knee arthroplasty: 77 cases compared with a matched control group (Bollars et al., 2020)* 3. *Robotics in Arthroplasty: A Comprehensive Review (Jacofsky & Allen, 2016)* 4. *Threshold for Computer- and Robot-Assisted Knee and Hip Replacements in the English National Health Service (Burn et al., 2020)* 5. *Alignment of the lower extremity mechanical axis by computer-aided design and application in total knee arthroplasty (Zhang et al., 2016)* 6. *Efficacy of a novel iPod-based navigation system compared to traditional navigation system in total knee arthroplasty (Mullaji & Shetty, 2017)* 7. *The Impact of Pinless Navigation in Conventionally Aligned Total Knee Arthroplasty (Koenen et al., 2018)* 8. *Alignment in Total Knee Arthroplasty by the Use of an iPod-Based Navigation System (Koenen et al., 2016)* 9. *Improving outcomes in total knee arthroplasty-do navigation or customized implants have a role? (Beal et al., 2016)*

Appendix B

Table 9: *Background Information on Interviews*

Interview#	Domain	Interviewee's Position / Patient Details	Duration
P1	Patient	Male, age 58 TKA in 2018, Switzerland	55:11
P2	Patient	Female, age 75, TKA in 2021, Switzerland	28:50
P3	Patient	Male, age 56, TKA in 2020, Switzerland	29:14
P4	Patient	Male, age 69, TKA in 2020, Switzerland	18:14
P5	Surgeon	Head Physician and Clinic Director	35:57
P6	Surgeon	Head Physician Knee Surgery	29:34
P7	Surgeon	Head Physician Knee Surgery	20:25
P8	Surgeon	Surgeon and Medical Officer for Insurances	38:35
P9	Physiotherapist	Team Leader Physiotherapy Hip, Knee and Foot	35:35
P10	Physiotherapist	Head of Medical Support Areas	33:09
P11	Physiotherapist	Deputy Managing Director	24:05
P12	Regulator	Senior Management Position (BAG)	25:04
P13	Regulator	Senior Scientific Position (EU-Commission)	29:13
P14	Insurer	Head of Service Purchasing	24:08
P15	Insurer	Division Manager Tariff and Benefits	35:26
P16	Insurer	CIO and Member of the Management Board	28:03
P17	Insurer	Negotiation Leader Service Purchasing	39:40
P18	Industry	VP and Worldwide General Manager of Robotics	28:50
P19	Industry	Marketing Manager GSM Knees	39:22
P20	Industry	Product Manager Knee Reconstructive Surgery	28:32
P21	Industry	Country Lead Medical Devices Switzerland	27:04
P22	Industry	Marketing Manager Global Strategy Marketing	24:02
P23	Industry	Senior Plant Quality Manager	20:57
P24	Industry	Vice President & General Manager Connectivity	14:17
P25	Industry	Vice President Strategic Solution EMEA	25:23
P26	Industry	Global President Robotics & Technology	23:10
P27	Industry	Sales Representative Recon	22:55

Appendix C

1. Which of the following Digital Technologies within the patient journey of TKA / TKR do you consider to be relevant today? (multiple choice)

   A. 3D Printing
   B. Big Data
   C. Wearables
   D. Virtual Healthcare
   E. Robotics
   F. None of the above (name trend)

1.1 What further notes and thoughts do you have on these digital technology trends? (open question)

2. Which of the following Digital Technologies within the patient journey of TKA / TKR do you consider to be the be the most relevant and promising in the future (positive impact of the patient)? (single choice)

   A. 3D printing
   B. Big Data
   C. Wearables
   D. Virtual Healthcare
   E. Robotics
   F. None of the above (name trend)

2.1 Why do you think this is the most relevant and promising digital technology in future? (open question)

3. What is the value created by Digital Technologies to you or by you as a key stakeholder? (open question)

4. How do you think Digital Technologies may have an influence on your key stakeholder role within the TKA/ TKR journey? (open question)

5. Why do think these Digital Technologies are not yet broadly established? (open question)

Appendix D

Information from the HSG library team regarding the sequencing of results according to relevance (free translation).

The relevance of the hits is calculated in the background by the system based on a large number of data. A proprietary algorithm working in the background uses two ranking systems, which are then merged for the display:

1. Dynamic Rank: How well do the search terms used by the users fit the metadata of the documents stored in the system?
    a. In which fields do the search terms match? The highest values are given for matches for titles or keywords
    b. Matches with rarer terms are rated higher than with general terms
    c. The frequency of matches in a document is weighted
    d. Verbatim matches are weighted higher
    e. Phrase searches with a match are weighted higher
2. Static Rank: an internal evaluation of all listed documents
    a. Resource type: a book scores more highly than a book review
    b. Publication date: current documents are given weighted higher
    c. Scientific articles from peer-reviewed journals are weighted higher
    d. If available: number of citations in articles
    e. If available: ranking for scientific journals
    f. Bonus malus for content that has not been assigned to an author