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Understanding Patient Perspectives Regarding Remote Monitoring Devices Following Total Joint Replacement

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ABSTRACT

Background: Advances in smart technology have expanded into the field of orthopedic surgery to deliver enhanced patient care. Smart technology has also raised important issues regarding protected patient information. The purpose of this study is to determine patient preferences regarding smart technology in their postarthroplasty care.

Methods: Patient surveys were administered in the office setting of 2 adult reconstructive orthopedic surgeons during a 4-week period. Surveys queried patient demographics, twelve yes/no questions, five continuous agree/disagree statements, and a single free-text question. Logistic regression and statistical significance testing were performed.

Results: Of the study patients, 83.6% were willing to wear a device. Women were more likely to consent to a monitoring device and have activity data collected than men ($P < .05$). Younger patients were more likely to consent to a device and have data collected than octogenarians. Nearly 90% of respondents indicated peace of mind with data being constantly tracked. However, 64% of respondents had hesitations about a surgically implanted device that was independent of a previous arthroplasty surgery ($P < .05$).

Conclusions: Patients are comfortable with smart technology being involved in their postoperative care, especially younger patients and women. Older individuals, possibly with less experience using smart technology in their lives, were not as willing to wear smart devices or have their data collected. Nearly two-thirds of patients had hesitations about surgically implanted smart devices. Further investigation is needed to understand hesitations concerning smart implants as the orthopedic community enters an era of commercially available smart implants in total joint arthroplasty.

Introduction

Advances in smart technology have expanded into the field of orthopedic surgery to deliver enhanced patient care and improve outcomes, while decreasing health-care expenditures [1–3]. Smart technology has been incorporated into several applications ranging from external wearable trackers, intraoperative guides facilitating surgical precision, to fully implantable devices that each can provide diagnostic and therapeutic modalities to the physician and patient [4–7].

In the application of total knee arthroplasty (TKA), smart technology can provide assistance intraoperatively in the alignment, sizing, and balance of the patient's TKA [4]. Recently, implanted sensors, such as the Persona IQ (Zimmer Biomet, Warsaw, IN), were developed as a stem attachment to the tibial TKA component and can track step count, distance ambulated, range of motion, average walking speed, stride length, and cadence. Designs have been created for smart implants with the ability to detect early infection through physical stimuli, such as temperature or pH, and potentially antibiotic elution as a treatment for infection vs a return trip to the operating room [8].

Smart technology has also brought up important issues regarding protected patient information and its compliance with the Health Insurance Portability and Accountability Act of 1996. With a plethora of orthopedic implants currently in use and an

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increasingly educated patient population, some patients have expressed concerns and apprehensions surrounding the use of smart technology in relation to their privacy [9]. Currently, there is a paucity of literature investigating the patient perspective and attitudes toward smart technology and smart implants. The purpose of this study is to determine whether patients prefer smart technology and implants in their care vs conventional, nonsmart modalities. Secondary measures will assess patients' sociodemographic factors that may guide their preferences. Our hypothesis is that younger patients will prefer the use of smart technology.

Material and methods

This was a level IV, multicenter, cross-sectional, survey study with the primary purpose to ascertain patient preferences relating to smart technology. Approval from our institution's review board was obtained prior to the initiation of this study.

Patient surveys were administered in the outpatient office setting of two fellowship-trained adult reconstructive orthopedic surgeons at two locations over a 4-week period. A consecutive series of patients were offered participation in this study, while excluding patients younger than 18 years and non-English speakers. Surveys queried patient demographics, 12 binary yes/no questions regarding smart technology usage, 5 responses measured with a Likert scale, and 1 free-text question (Fig. 1). All paper survey responses were transcribed using REDCap electronic data-capture tools hosted at Northwell Health [10,11]. For the free-text question regarding patients' concerns about smart technology, responses were categorized into one of six categories: (1) privacy, (2) safety, (3) necessity, (4) cost, (5) other, (6) no-response listed.

Prior to analysis, the data were cleaned and coded. One patient survey was eliminated for being incomplete. Race was coded as white vs non-white, while Ethnicity was coded as Hispanic or Latino vs not Hispanic or Latino. For both race and ethnicity, the response option of “unknown/declined to answer” was removed from any analysis that included either variable. Body mass index (BMI) was categorized based on the Centers for Disease Control and Prevention guidelines. Given the large number of respondents in the obese range, this was further divided into obesity class I (BMI 30.0 − 34.9) and obesity class II - III (BMI >35.0 − 39.9 and BMI >40, respectively) [12].

Using SAS v9.4 (SAS Institute, Cary, NC), univariate analysis was used to determine the characteristics of the study population by gender, age grouping, race, and ethnicity. Chi-square testing was used to determine if specific survey question responses varied significantly by any of these demographic characteristics. Logistic regression models were then fit to describe the magnitude of these differences. A post-hoc power analysis was also performed using SAS v9.4, setting the probability level at 0.05, as this is the same as the *P* value utilized.

Results

A total of 293 surveys were completed. Demographic information was tabulated for all respondents (Table 1). The majority of patients completing surveys were female and white, not Hispanic or Latino. Approximately 50% of respondents had undergone a previous joint arthroplasty surgery. Sixty percent of patients never used any kind of medical remote monitoring device.

Prior use of remote monitoring devices

Less than half of the respondents (39.6%) had previously used remote monitoring devices. Women were 1.9 times more likely to have previously used a monitoring device than their male counterparts ($P < .005$). Compared to individuals aged 80-89 years, younger individuals were more likely to have previously used a monitoring device, with the likelihood increased with younger age groups. Regarding obesity, individuals with lower BMI were more likely to have previously used a monitoring device. The likelihood increased as BMI decreased, with those of normal weight being the most likely ones to have used a device in the past ($P < .05$) (Table 2).

Willingness to wear remote monitoring devices and/or surgically implanted remote monitoring devices

Overall, 83.6% of patients were willing to wear a remote monitoring device. Women were 2.0 times more likely to be willing to wear a monitoring device than men ($P < .05$) (Table 3). Individuals who stated that they have previously worn a monitoring device were 7.0 times more likely to state that they would be willing to wear one again ($P < .001$). Individuals aged 60-69 years were 4.0 times more likely to wear a monitoring device than individuals aged 80-89 years ($P < .01$). No significance was found when considering race, ethnicity, or BMI. When examining hesitations about surgically implanted devices, 63.8% of patients had concerns, although there were no significant associations found based on patient demographics (Table 4). However, those with hesitations to having a device surgically inserted were 90% less likely to be willing to try a device ($P < .0001$). Younger individuals and women were much more likely to be comfortable wearing a device on their hip or wrist than older individuals and men ($P < .05$ and $P < .01$, respectively). Additionally, younger individuals and women were more likely to feel comfortable having a data-collection unit next to their bed at night ($P < .01$ and $P < .05$, respectively). Finally, younger individuals and women were much more likely to state that they would log into an online portal to monitor their own progress ($P < .001$ and $P < .05$, respectively).

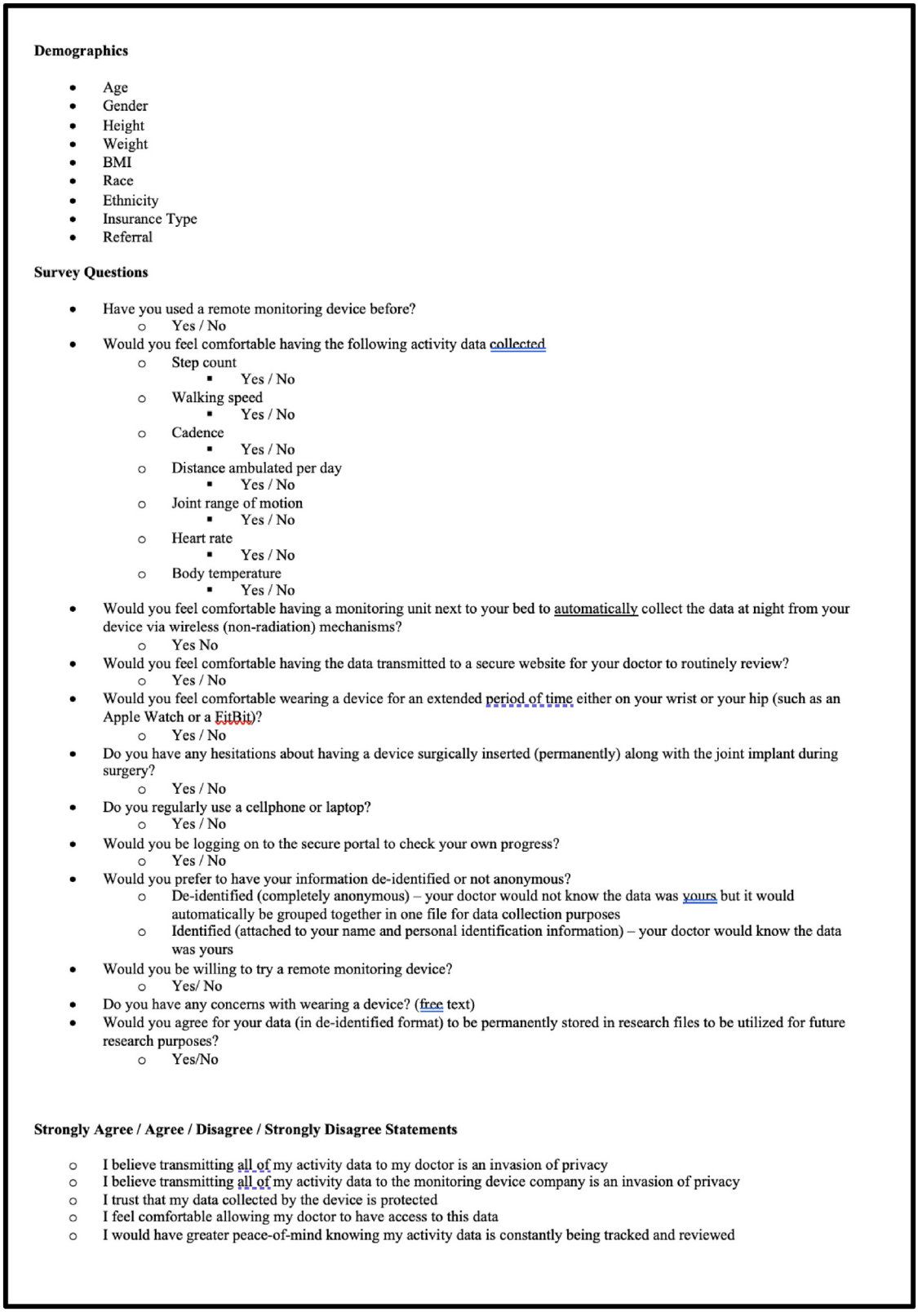
Patient comfort regarding tracking of activity data

Of the study patients, 84.3% were comfortable having their activity data collected. Women were 2.4 times more likely to be comfortable with having their activity data collected than men ($P < .05$). Individuals who had previously used a monitoring device were 31 times more likely to feel comfortable with their data being collected than those without any experience in using a monitoring device ($P < .001$). All individuals who said they would be comfortable with activity data being collected stated “yes” to all seven sub-options (step count, walking speed, cadence, distance ambulated per day, joint rom, heart rate, and body temperature). Younger individuals, 60 − 69 years and <60 years, were 4 and 4.9 times more likely, respectively, to feel comfortable with having their activity data collected than older individuals aged 80-89 years ($P < .01$) (Table 5). The majority of respondents (61%) stated that they would agree to their data not being anonymous and felt comfortable with data being attached to their identifying information. Furthermore, younger individuals and women were more likely to be comfortable with their data being transmitted to a secure website than older individuals and men ($P < .01$ and $P < .05$, respectively). Individuals who trust that their data collected by a smart device are secure were 13.8 times more likely to try the device than those who did not trust their data would be protected ($P < .001$). Women were twice as likely to agree that their data would be private compared to men ($P < .05$)

Regarding invasion of privacy

Those who agreed that transmitting all data to their doctor is an invasion of their privacy were 92% less likely to be willing to try the

device than those that disagreed ($P < .0001$). Women were 3.3 times more likely to disagree that this would be an invasion of privacy than men ($P < .01$). Those who said transmitting to a company is not an invasion of privacy were 6.5 times more likely to be willing to try the device ($P < .0001$). Women were 2.5 times more likely to disagree that this would be an invasion of privacy than men ($P < .001$).



Demographics

- Age
- Gender
- Height
- Weight
- BMI
- Race
- Ethnicity
- Insurance Type
- Referral

Survey Questions

- Have you used a remote monitoring device before?
  - Yes / No
- Would you feel comfortable having the following activity data collected
  - Step count
    - Yes / No
  - Walking speed
    - Yes / No
  - Cadence
    - Yes / No
  - Distance ambulated per day
    - Yes / No
  - Joint range of motion
    - Yes / No
  - Heart rate
    - Yes / No
  - Body temperature
    - Yes / No
- Would you feel comfortable having a monitoring unit next to your bed to automatically collect the data at night from your device via wireless (non-radiation) mechanisms?
  - Yes No
- Would you feel comfortable having the data transmitted to a secure website for your doctor to routinely review?
  - Yes / No
- Would you feel comfortable wearing a device for an extended period of time either on your wrist or your hip (such as an Apple Watch or a FitBit)?
  - Yes / No
- Do you have any hesitations about having a device surgically inserted (permanently) along with the joint implant during surgery?
  - Yes / No
- Do you regularly use a cellphone or laptop?
  - Yes / No
- Would you be logging on to the secure portal to check your own progress?
  - Yes / No
- Would you prefer to have your information de-identified or not anonymous?
  - De-identified (completely anonymous) – your doctor would not know the data was yours but it would automatically be grouped together in one file for data collection purposes
  - Identified (attached to your name and personal identification information) – your doctor would know the data was yours
- Would you be willing to try a remote monitoring device?
  - Yes/ No
- Do you have any concerns with wearing a device? (free text)
- Would you agree for your data (in de-identified format) to be permanently stored in research files to be utilized for future research purposes?
  - Yes/No

Strongly Agree / Agree / Disagree / Strongly Disagree Statements

- I believe transmitting all of my activity data to my doctor is an invasion of privacy
- I believe transmitting all of my activity data to the monitoring device company is an invasion of privacy
- I trust that my data collected by the device is protected
- I feel comfortable allowing my doctor to have access to this data
- I would have greater peace-of-mind knowing my activity data is constantly being tracked and reviewed

Figure 1. Sample survey administered to patients in the outpatient office.

Table 1
Demographic data for all patient respondents.

Demographic data	n (%)
Total observations (N)	293
Age (range 26-89) (mean = 66)	
<60	67 (22.9)
60-69	115 (39.2)
70-79	83 (28.3)
80-89	28 (9.6)
Gender	
Female	184 (62.8)
Male	109 (37.2)
Race	
White	225 (76.8)
Non-white	59 (20.1)
Asian	7 (2.4)
Black or African American	29 (9.9)
Other	23 (7.8)
Unknown/declined to answer	9 (3.1)
Ethnicity	
Hispanic or Latino	20 (6.8)
Not Hispanic or Latino	254 (87.0)
Unknown/declined to answer	18 (6.2)
Previous arthroplasty surgery	
Yes	129 (44.0)
No	164 (56.0)
Used a remote device before	
Yes	116 (39.6)
No	177 (60.4)

Table 3
Patient responses for willing to wear a device.

Willing to wear a device	Yes, n (%)	No, n (%)	*P* value
Overall	244 (83.6)	48 (16.4)	
Gender			
Male	85 (78.0)	24 (22.0)	-
Female	159 (86.9)	24 (13.1)	**<.05**
Age			
<60	58 (86.6)	9 (13.4)	**<.05**
60-69	102 (89.5)	12 (10.5)	**<.01**
70-79	65 (78.3)	18 (21.7)	.19
80-89	19 (67.8)	9 (32.1)	-
Race			
White	189 (84.4)	35 (15.6)	.36
Non-white	47 (79.7)	12 (20.3)	-
Asian	7 (100.0)	0 (0.0)	
Black or African American	26 (89.7)	3 (10.3)	
Other	14 (60.9)	9 (39.1)	
Unknown/declined to answer	8 (88.9)	1 (11.1)	
Ethnicity			
Hispanic or Latino	15 (75.0)	5 (25.0)	-
Not Hispanic or Latino	213 (84.2)	40 (15.8)	.42
Unknown/declined to answer	15 (83.3)	3 (16.7)	
BMI			
Normal weight (18.5-24.9)	56 (91.8)	5 (8.2)	.23
Overweight (25.0-29.9)	70 (80.5)	17 (19.5)	.93
Obese class I (30.0-34.9)	65 (80.3)	16 (19.7)	.75
Obese class II/III (>35.0)	53 (84.1)	10 (15.9)	
Previously worn device	177 (60.4)	116 (39.6)	**<.001**

P values achieving statistical significance are listed in bold font.

Free-text responses regarding patient concerns

Twenty-seven percent of patient concerns were regarding safety of surgically implanted smart devices, while 18% of responses were concerns about privacy. A small number of concerns questioned the medical necessity of smart implants (3 patients) and the costs associated with smart implants (2 patients). Nine percent of responses were not able to be discretely categorized. Forty-four percent of respondents did not include a response. Examples of free-text responses include

Patient #182: "*I hope it doesn't cause any medical interactions.*"

Patient #3: "*Worried about my privacy beyond a doctor reviewing it, if it were hacked what would people do with it?*"

Patient #163: "*I don't want anything extra and too much technology.*"

Patient #270: "*It's a foreign object and an invasion of privacy.*"

Discussion

The use of smart technology has been shown to improve patient outcomes in a variety of applications. A review by Ledet et al. found

Table 2
Patient responses regarding prior use of remote monitoring devices.

Used remote monitoring device before	Yes, n (%)	No, n (%)	*P* value
Overall			
Gender			
Male	35 (32.1)	74 (67.9)	-
Female	81 (44.0)	103 (56.0)	**<.05**
Age			
<60	34 (50.8)	33 (49.32	**<.001**
60-69	48 (41.7)	67 (58.3)	**<.05**
70-79	31 (37.4)	52 (62.6)	**<.05**
80-89	3 (10.7)	25 (89.3)	-
Race			
White	90 (40.0)	135 (60.0)	.64
Non-white	21 (35.6)	38 (64.4)	-
Asian	2 (28.6)	5 (71.4)	
Black or African American	15 (51.7)	14 (48.3)	
Other	4 (17.4)	19 (82.6)	
Unknown/declined to answer	5 (55.6)	4 (44.4)	
Ethnicity			
Hispanic or Latino	7 (35.0)	13 (65.0)	
Not Hispanic or Latino	102 (40.2)	152 (59.8)	.74
Unknown/declined to answer	6 (33.3)	12 (66.7)	-
BMI			
Normal weight (18.5-24.9)	29 (47.5)	32 (52.5)	**<.05**
Overweight (25.0-29.9)	35 (40.2)	52 (59.8)	**<.05**
Obese class I (30.0-34.9)	33 (40.7)	48 (59.3)	**<.05**
Obese class II/III (>35.0)	19 (29.7)	45 (70.3)	-

P values achieving statistical significance are listed in bold font.

Table 4
Patient responses for hesitations about surgically implanted devices.

Hesitations about surgically implanted device	Yes, n (%)	No, n (%)	*P* value
Overall	187 (63.8)	106 (36.2)	
Gender			
Male	71 (65.1)	38 (34.9)	-
Female	116 (63.0)	68 (37.0)	.73
Age			
<60	48 (71.6)	19 (28.4)	.37
60-69	72 (62.6)	43 (37.4)	.84
70-79	50 (60.2)	33 (39.8)	.90
80-89	17 (60.7)	11 (39.3)	-
Race			
White	146 (64.9)	79 (35.1)	.05
Non-white	34 (57.6)	25 (42.4)	-
Asian	3 (42.9)	4 (57.1)	
Black or African American	14 (48.3)	15 (51.7)	
Other	17 (73.9)	6 (26.1)	
Unknown/declined to answer	7 (77.8)	2 (22.2)	
Ethnicity			
Hispanic or Latino	14 (70.0)	6 (30.0)	-
Not Hispanic or Latino	158 (62.2)	96 (37.8)	.23
Unknown/declined to answer	14 (77.8)	4 (22.2)	
BMI			
Normal weight (18.5-24.9)	38 (62.3)	23 (37.7)	.50
Overweight (25.0-29.9)	50 (57.5)	37 (42.5)	.24
Obese class I (30.0-34.9)	55 (67.9)	26 (32.1)	.81
Obese class II/III (>35.0)	44 (68.8)	20 (31.3)	-

Table 5
Patient responses regarding comfortability of having activity data collected.

Comfortable having activity data collected	Yes, n (%)	No, n (%)	*P* value
Overall	247 (84.3)	48 (15.7)	
Gender			
Male	85 (78.0)	24 (22.0)	
Female	159 (86.9)	24 (13.1)	**<.05**
Age			
<60	60 (89.5)	7 (10.5)	**<.01**
60-69	102 (88.7)	13 (11.3)	**<.01**
70-79	66 (79.5)	17 (20.5)	.14
80-89	19 (67.9)	9 (32.1)	-
Race			
White	191 (84.9)	34 (15.1)	.50
Non-white	48 (81.4)	11 (18.6)	-
Asian	6 (85.7)	1 (14.3)	
Black or African American	28 (96.6)	1 (3.4)	
Other	14 (60.9)	9 (39.1)	
Unknown/declined to answer	8 (88.9)	1 (11.1)	
Ethnicity			
Hispanic or Latino	15 (75.0)	5 (25.0)	-
Not Hispanic or Latino	216 (85.0)	38 (15.0)	.30
Unknown/declined to answer	15 (83.3)	3 (16.7)	
BMI			
Normal weight (18.5-24.9)	56 (91.8)	5 (8.2)	.21
Overweight (25.0-29.9)	70 (80.5)	17 (19.5)	.92
Obese class I (30.0-34.9)	67 (82.7)	14 (17.3)	.87
Obese class II/III (>35.0)	54 (84.4)	10 (15.6)	-
Previously used a monitoring device	177 (60.4)	116 (39.6)	**<.001**

P values achieving statistical significance are listed in bold font.

that current use of smart technology and implants have led to improvements in component design, surgical technique, and rehabilitation protocols [1]. The use of a commercially available smart tibial tray component that functions to demonstrate contact forces intraoperatively has been shown to increase patient satisfaction and decrease complications [13,14]. In the setting of total hip arthroplasty, smart implants have helped guide physical therapy protocols postoperatively [15]. Additionally, smart implants have been shown to detect loosening of THA components, albeit in vitro at this time [16].

As the first commercially available, surgically implanted smart device has emerged, the topic of patient preferences regarding smart implants and smart devices has been a timely matter. Despite industry trends leading toward a proliferation of smart technology, this study, to our knowledge, is the first that examines patient preference. Our findings reveal that patients do feel comfortable with smart technology being involved in their postoperative arthroplasty care. Wearable technology has been available commercially for many years as both medical and recreational devices. Combined with the ubiquitous nature of smart phones, patients have likely grown accustomed to the use of smart technology and external wearable devices. Women and younger individuals, especially those younger than 60 years, appear to be the most willing to use smart technology in their arthroplasty care as well as trusting that data are secure. Older individuals, possibly with less experience using smart technology in their daily lives, may have been less willing or trusting to use these devices following total joint arthroplasties.

A recent study by Kurtz et al. examined patient perceptions specific to wearable and smartphone technology in the setting of hip osteoarthritis and arthroplasties [17]. They compared patients undergoing THA to nonoperatively treated patients and found that those treated operatively had a much stronger interest in smart technology especially when asked about devices constantly tracking location and data [17]. This study did not, however, ask patients about preferences regarding surgically implanted devices. Another study examined the clinician's perspective relating to wearable technologies in the treatment of osteoarthritis by conducting interviews with 13 physicians including 5 orthopedic surgeons. This study found strong support for wearable devices to enhance patient care and outcomes [18].

While patients are generally very accepting of smart technology inclusive of wearable devices, they are much more hesitant about permanent, surgically implanted devices. Similar to wearable implants, older male patients are much less likely to consent to the use of a smart implant. Patients who also do not have experience with smart devices were much less likely to use a smart implant in their care. Most concerns expressed regarding the use of implanted devices centered around patient safety and privacy. A notable difference, compared to an external device, is that patients felt that they had less control regarding these devices, which may raise significant apprehensions.

In one of the current commercially available implanted devices, the Persona IQ (Zimmer Biomet, Warsaw, IN), data are securely held by the device company and is readily available to both the operative surgeon and the patient for postoperative care or biomedical research, among other uses. Data are not available to the company unless there is an agreement to share information in a blinded fashion. Ultimately, the patient owns these data, but the authors are unaware if any of these data can be used by device companies for either industry-sponsored research or targeted marketing. Patients' concerns of how their data are utilized are not uncommon. The practice of patient data being sold to third-party companies frequently occurs. Most notably, the United Kingdom's publicly funded health-care system, the National Health Service, uses patient data for internal research and will sell the data to third-party organizations [19]. There have also been lawsuits, both in the United States and the United Kingdom, in which marketing data were sold that infringed on patient privacy [20].

This study is not without its limitations. First, this study included a consecutive series of patients presenting to two arthroplasty offices and did not necessarily select for those who were considering total joint arthroplasty. Additionally, the survey utilized was not previously validated and may have introduced bias. Our sample size of 293 represented 4 weeks of patient enrollment in two demographically different office settings. However, nearly two-thirds of respondents were female and greater than three-fourth were white and non-Hispanic, which also may have introduced bias into our study although this does appear to accurately describe the patient population in our practice. Despite this factor, our post-hoc power analysis did indicate sufficient power to find significant results when those significant results do in fact exist.

Conclusions

Overall, this study appears to be one of the first of its kind in gauging patient perceptions about smart technology including surgically implanted smart implants. While the current authors of this study have incorporated the use of robotics and navigation into their practice, smart technology and wearable devices are not presently utilized. This study was performed to gauge patient attitudes to help guide the authors' practice relating to smart technology as well as contributing to the existing body of orthopedic literature. Further investigation is needed to understand hesitations concerning smart implants as the orthopedic community enters an era of commercially available smart implants in total joint arthroplasty.

Conflicts of interest

J. R. Danoff is in the speakers' bureau of or gave paid presentations for Flexion Therapeutics; is a paid consultant for Acelrx and Surgical Specialties Corp.; is in the editorial board of

Arthroplasty Today; and is a committee member of the American Association of Hip and Knee Surgeons. M. Nett is a paid consultant for Insight Medical Systems; has stock or stock options in Stryker Corp.; and receives research support as principal investigator from 3M Health Care. The other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.10.006.

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