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Lived Experiences of Patients with IoT-Enabled Smart Implants in Postoperative Pain Management

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ABSTRACT

Advancements in IoT-enabled medical technologies have transformed postoperative pain management by introducing smart implants that provide real-time monitoring and automated regulation of patient recovery. However, few studies have investigated patients' subjective experiences, leaving a gap in understanding how they construct personal and emotional meanings while living with such devices. This raises the central question: How do patients perceive, adapt to, and internalize the use of IoT-based smart implants during recovery? Here, we apply an Interpretative Phenomenological Analysis (IPA) to explore the lived experiences of patients using IoT-enabled smart implants and uncover the essential meanings embedded in their recovery journeys. Data were collected through in-depth semi-structured interviews with twelve participants who underwent smart implant procedures in tertiary hospitals. The analysis revealed four central themes: trust and initial perceptions, psychological adaptation, data transparency and privacy concerns, and the balance between improved quality of life and emotional dependence. Participants described the transformative yet complex nature of integrating technology into their bodies, highlighting evolving relationships between autonomy, trust, and technological embodiment. These findings deepen our understanding of human-device interactions in postoperative care and underscore the need for patient-centered approaches in medical innovation. By revealing the personal, cultural, and emotional dimensions of recovery, this study provides valuable insights for improving clinical practices, enhancing healthcare policies, and guiding the design of future IoT-based medical devices..

INTRODUCTION

Technological innovations in healthcare have significantly transformed the management of postoperative pain, especially with the integration of IoT-enabled smart medical implants (Mukhlis, Suradi, et al., 2023; Mukhlis, 2025b). These advancements reflect broader developments in digital health, where medical devices increasingly serve as interactive tools designed to enhance patient outcomes and facilitate real-time monitoring. In modern clinical practice, smart implants offer not only functional benefits such as automated pain regulation and continuous data transmission but also create a new dimension in how patients experience and relate to their bodies within technologically mediated care environments. While clinical effectiveness has been widely documented, little is known about the psychological, social, and emotional dimensions of living with such devices.

Within this context, the emergence of IoT-based medical technologies has introduced a complex interplay between technology, human perception, and personal identity (Joseph et al., 2020; Tyler et al., 2019). While the clinical effectiveness of smart implants has been extensively documented in terms of reducing pain and improving mobility, less is understood about how patients experience living with such devices on a psychological, social, and emotional level. Postoperative recovery is not only a biomedical process but also a deeply personal and subjective journey influenced

by individuals' cultural beliefs, trust in medical systems, and sense of bodily autonomy. These subjective experiences are often overlooked in studies focused solely on clinical performance and measurable health outcomes.

Exploring these experiences is crucial because the adoption of medical technologies occurs within socially and culturally embedded contexts (Isiwele et al., 2025; Sharma et al., 2019). Patients' perceptions of trust, privacy, and control over their health data, as well as their evolving relationship with technology integrated into their bodies, shape their overall recovery and well-being. By understanding these lived experiences, healthcare providers and policymakers can better align technological innovation with patients' personal values, expectations, and cultural realities.

Given the increasing integration of IoT-based implants in clinical practice, there is a growing need for in-depth qualitative inquiry to uncover the meanings patients ascribe to their experiences (Mukhlis, Arifin, Ridwan, & Zulbaidah, 2025; Mukhlis, Arifin, Ridwan, Zulbaidah, et al., 2025). The phenomenological approach is particularly well-suited to this task because it prioritizes the subjective essence of lived experiences, enabling a deeper understanding of how individuals interpret and navigate their interactions with medical technologies within their social and personal worlds. This focus on meaning-making offers insights that extend beyond clinical efficacy, contributing to more human-centered innovations in healthcare.

Building upon the broader developments in digital healthcare, research into patients' subjective experiences with medical technologies has become increasingly recognized as a critical field of inquiry (Delany et al., 2025a; Velayati & Ahmad, 2024). In the context of IoT-enabled smart implants, understanding how individuals perceive, adapt to, and live with these devices is essential, as such experiences extend beyond clinical outcomes to encompass psychological, social, and cultural dimensions. Numerous studies have demonstrated the clinical effectiveness of smart implants in reducing pain and improving recovery trajectories, yet these investigations have primarily relied on quantitative measures such as pain scores, mobility indices, and biometrics. While these indicators are valuable, they often overlook the lived realities and meaning-making processes that shape patients' interactions with medical technologies.

One of the main methodological challenges in this area lies in the inadequacy of quantitative approaches to fully capture the subjective, multifaceted, and contextualized nature of patient experiences (Barley & Southcott, 2019; Delany et al., 2025b). Questionnaires and standardized scales frequently fail to explore deeper emotional, cognitive, and identity-related dimensions, such as trust in technology, perceived bodily autonomy, and psychological adaptation following implantation. As a result, many existing studies provide only a partial understanding of how individuals interpret and internalize their experiences, leaving critical aspects of the phenomenon unexplored.

Furthermore, prior qualitative research on medical implants has often adopted descriptive frameworks that limit the depth of interpretive analysis (Mukhlis et al., 2024; Mukhlis, Maryam, et al., 2023). These studies tend to focus on surface-level observations rather than the underlying meanings that participants ascribe to their experiences within their sociocultural and personal contexts. Consequently, the complex interplay between technological embodiment, privacy concerns, emotional dependency, and identity reconstruction remains insufficiently addressed in the literature. This gap underscores the necessity of adopting a more interpretative phenomenological approach to better illuminate the essence of patients' lived experiences with IoT-based smart implants.

By narrowing the analytical lens toward phenomenology, this study seeks to contribute a more holistic and nuanced understanding of how patients engage with advanced medical technologies, how they construct personal meaning around their use, and how these experiences influence their recovery and quality of life.

Despite the rapid integration of IoT-enabled smart implants in clinical practice, much of the existing research has focused on evaluating their technical performance and clinical efficacy, including metrics such as pain reduction, improved mobility, and shortened recovery times (McGee et al., 2022). These studies commonly employ quantitative approaches that measure functional outcomes but overlook the subjective meanings patients construct around living with technologically embedded

medical devices. As a result, the psychosocial and experiential dimensions of recovery remain underexplored.

Existing frameworks for assessing patient outcomes tend to rely on standardized instruments and biomedical indicators, which provide limited insight into the personal, cultural, and emotional contexts shaping patients' experiences (Cayci et al., 2024; Madanian et al., 2023). While these approaches capture the "what" of recovery, they fail to reveal the "how" and "why" behind patients' trust in technology, adaptation to bodily integration, and negotiation of privacy and autonomy. Consequently, critical questions remain unanswered regarding how patients perceive the presence of smart implants, interpret their role in everyday life, and reconcile technological dependence with personal identity.

Moreover, limited qualitative studies have been conducted, and among those available, most adopt descriptive models that insufficiently address the essence of the phenomenon (Arthurs et al., 2022; Gogoshin, 2024). Without deeper interpretative inquiry, existing literature lacks the capacity to illuminate the complex interplay between human-device interaction, psychological adaptation, and sociocultural influences. This methodological gap restricts understanding of the broader implications of smart implant usage within diverse healthcare settings.

To address this limitation, adopting an interpretative phenomenological approach (IPA) provides an alternative pathway to uncover rich, nuanced, and contextualized insights into patients' lived experiences. By prioritizing participants' own narratives and meaning-making processes, this study seeks to bridge the knowledge gap and offer a more holistic understanding of how patients experience, internalize, and adapt to IoT-based smart implants within their postoperative recovery journey.

Recent studies have examined the integration of IoT-based smart implants in healthcare and highlighted their clinical benefits, such as pain reduction and improved recovery rates (Bazzano et al., 2019; Holden et al., 2020). However, limited research has explored the subjective experiences of patients living with these technologies, leaving significant gaps in understanding the personal, social, and emotional aspects of recovery. Existing literature suggests that patients' perceptions of trust, bodily autonomy, and privacy strongly influence their adaptation to medical technologies. Despite these insights, few studies have adopted interpretative approaches capable of uncovering the deeper meanings behind patients' lived experiences. This limitation underscores the necessity of employing a phenomenological perspective to illuminate the essence of these interactions.

To address this gap, this study applies an Interpretative Phenomenological Analysis (IPA) to explore patients' experiences with IoT-enabled smart implants during postoperative recovery (Murala et al., 2023; Rincón et al., 2025). This approach was chosen because it prioritizes participants' personal narratives and enables a deeper understanding of how meaning is constructed in relation to medical technologies. By focusing on subjective interpretations, IPA allows the study to uncover the psychological, emotional, and cultural dimensions of living with a smart implant. This method responds directly to the unresolved questions identified in the previous section by revealing how patients perceive, adapt to, and internalize their experiences. The findings are expected to contribute both theoretical insights and practical implications for patient-centered medical innovation.

This article is organized into several sections to ensure clarity and logical flow. The Introduction outlines the research background, knowledge gap, and objectives of the study (Altman et al., 2020; Toivonen et al., 2019). The Method section describes the phenomenological design, data collection procedures, and analytical framework used. The Results section presents the emergent themes derived from participants' narratives, supported by direct quotations to preserve authenticity. Finally, the Discussion and Conclusion sections interpret the findings within broader theoretical and clinical contexts, highlighting contributions to knowledge and implications for future research.

RESEARCH METHODS

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Study Design

This study adopted an interpretative phenomenological approach (IPA) to explore the subjective experiences of patients using IoT-based smart implants for postoperative pain management (McNabb, 2015). Phenomenology was selected due to its focus on understanding the lived experiences of individuals and uncovering the essential meanings behind their interactions with technological medical devices. The IPA approach emphasizes an in-depth interpretation of participants' personal narratives within their sociocultural and clinical contexts. By applying this framework, the study sought to capture the multidimensional and nuanced meanings embedded in patients' accounts, making it particularly suitable for examining human-device interaction in healthcare.

Participants

Participants consisted of individuals who had undergone IoT-enabled smart implant procedures for postoperative pain management within the last 12 months in tertiary hospitals (Hillman & Radel, 2018; Lutz & Knox, 2014). A purposive sampling strategy was applied to ensure the inclusion of participants with direct and relevant experiences.

Inclusion criteria included:

- Adults aged 25 to 60 years
- Underwent smart implant-assisted postoperative pain therapy
- Willingness and ability to articulate personal experiences

Exclusion criteria included:

- Individuals with cognitive impairments that could hinder accurate recall
- Patients experiencing active psychiatric conditions
- Participants unable to communicate in the interview language

A total of 12 participants were involved, consisting of 7 females and 5 males, with an average age of 42.8 years (SD = 8.5). Diverse educational, occupational, and socioeconomic backgrounds were represented to enhance contextual richness.

Data Collection

Data were collected through in-depth semi-structured interviews guided by a protocol developed from existing literature on phenomenological inquiry and IoT-enabled medical technologies (Migdal, 2018). The interview guide consisted of open-ended questions exploring participants' perceptions, emotions, and experiences throughout their journey with smart implants.

1. Mode of interview: Face-to-face sessions conducted in private hospital consultation rooms
2. Duration: Each interview lasted between 45 and 75 minutes
3. Tools used: Digital audio recorders and detailed field notes
4. Environment: Neutral and comfortable settings were ensured to encourage open reflection

Participants were invited to share their experiences freely, while probes were used to elicit deeper insights when necessary. Interviews continued until data saturation was achieved, ensuring comprehensive thematic coverage.

Data Analysis

Data were analyzed using the Interpretative Phenomenological Analysis (IPA) framework, following a six-step iterative process to extract essential meanings (Carreiras & Castro, 2012):

1. Immersion: Verbatim transcripts were read repeatedly to gain familiarity with participants' narratives.
2. Initial Coding: Significant statements, phrases, and expressions were identified and labeled as preliminary meaning units.
3. Theme Development: Codes were clustered into emerging themes that reflected shared experiential patterns.

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4. Cross-Case Comparison: Themes were compared across all participants to identify convergences and divergences.
5. Synthesis of Essential Structures: Core experiential meanings were distilled and organized to reflect the phenomenon's essence.
6. Validation: Themes were refined using member checking to ensure accuracy and credibility.

NVivo 14 software was utilized to support data organization and facilitate systematic coding but did not replace manual interpretative engagement.

Ethical Considerations

Ethical approval for this study was obtained from the Institutional Research Ethics Committee of the participating hospitals (Approval No. XXXX/2025). All participants were provided with detailed study information, and written informed consent was obtained prior to participation.

RESULTS

Trust and Initial Perceptions of Smart Implants

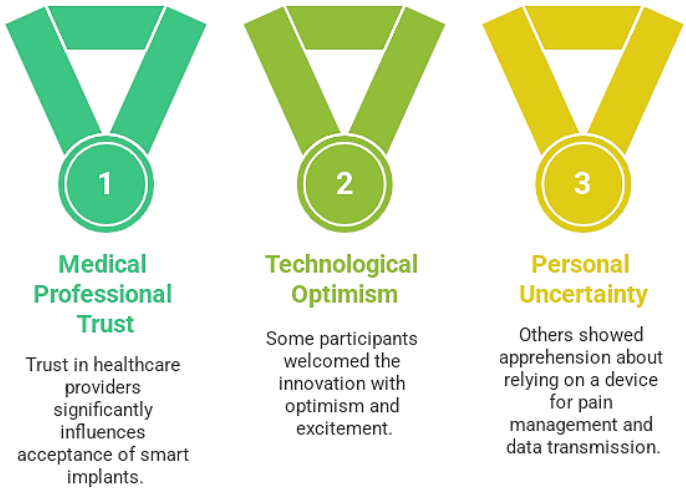
Participants expressed mixed feelings when first introduced to the IoT-based smart implant technology. While some welcomed the innovation with optimism, others showed apprehension about relying on a device to manage pain and transmit health data remotely.

One participant shared:

"At first, I was amazed by the idea that this small device could control my pain and send updates to the doctor… but I was also worried about what would happen if the system failed." (P3)

This duality reflected a balance between technological trust and personal uncertainty. Participants generally reported that their decision to consent was influenced by their confidence in medical professionals, indicating that trust in healthcare providers was a key factor enabling acceptance of the device.

Key Factors Influencing Smart Implant Acceptance



Embodied Experience and Psychological Adaptation

Participants described significant bodily and emotional adjustments following the implantation. Initially, many reported heightened self-awareness and anxiety, feeling "monitored" by the device. Over time, however, they gradually normalized the presence of the implant as part of their identity.

For example:

"The first week, I felt like a machine… I couldn't sleep because I kept thinking there was a device inside me. But after a while, I stopped noticing it it became part of me." (P6)

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This adaptation process revealed the psychological negotiation between technological embodiment and personal autonomy. Importantly, participants highlighted the role of family support and healthcare counseling in helping them cope during the early adjustment period.

Data Transparency, Privacy, and Control

Another dominant theme concerned data security and privacy. Since the implant transmitted real-time pain data to clinicians via IoT systems, participants raised concerns about who could access their health information and whether they retained control over it.

One participant questioned:

"I know the device sends my data to the hospital, but who else can see it? What if someone hacks it? It's my body, my information." (P4)

This highlights a critical ethical dimension of integrating IoT in medical devices: patients' perceived loss of control over personal health data. Despite these concerns, participants generally trusted hospital systems but called for greater transparency regarding data access and usage policies.

Improved Quality of Life Versus Emotional Dependence

While most participants reported significant pain reduction and improved mobility, several expressed emotional dependency on the device. They developed heightened reliance on its monitoring and pain-regulating functions, which influenced their confidence in recovery.

One participant reflected:

"Before the implant, I couldn't walk without pain. Now I can walk again, and that feels like freedom… but I also keep thinking, 'What if the device stops working?'" (P1)

This demonstrates a paradoxical experience: the implant empowered participants physically yet fostered subtle psychological dependency. These findings suggest that while technological interventions enhance clinical outcomes, they may also reshape patients' emotional relationships with their bodies and health.

Summary of Thematic Findings

Theme	Essence of Experience	Illustrative Quote
Trust and Initial Perceptions	Navigating between optimism and uncertainty	"I was amazed… but also worried."
Psychological Adaptation	Integrating the device into personal identity	"It became part of me."
Data Transparency & Privacy	Negotiating control over personal health data	"Who else can see my data?"
Quality of Life vs Dependence	Balancing empowerment with emotional reliance	"What if the device stops working?"

Essential Meaning of the Phenomenon

The findings illuminate a complex phenomenon: patients' experiences with IoT-based smart implants are simultaneously empowering and unsettling. The device offers significant relief and functional improvement, yet introduces new psychosocial and ethical considerations around trust, embodiment, autonomy, and privacy. Through these narratives, this study contributes a deeper understanding of how human-device interactions shape patients' perceptions, identities, and well-being in the context of postoperative care.

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DISCUSSION

Contribution of Findings to the Research Question

The primary research question sought to understand how patients perceive, experience, and adapt to living with IoT-based smart implants (Mukhlis & Abdullah, 2025; Mukhlis & Saidah, 2025). The findings offer nuanced insights into this phenomenon by illustrating that patients' experiences extend far beyond clinical outcomes. While participants acknowledged the device's role in reducing pain and restoring mobility, they also described profound shifts in self-perception, autonomy, and trust.

First, the results indicate that patients' adaptation to smart implants involves a dynamic negotiation between technological reliance and personal agency. Many participants expressed initial uncertainty and anxiety, gradually developing acceptance as the device became "part of their body", suggesting an evolving sense of technological embodiment. Second, privacy and data security emerged as salient concerns, highlighting participants' desire for transparency regarding data ownership and control. Finally, participants reported feelings of emotional dependence on the implant, reflecting a paradoxical relationship where the device provided empowerment but simultaneously reinforced vulnerability should the technology fail.

These insights collectively contribute to a deeper understanding of human-device interaction in the context of medical IoT technologies. By uncovering how patients construct meaning around their experiences, the study addresses gaps identified in the Knowledge Gap section and offers a patient-centered perspective that complements existing clinical frameworks.

Relation to Previous Literature and Theoretical Perspectives

The findings align with existing research demonstrating that digital health technologies influence not only clinical outcomes but also patients' psychosocial experiences. Previous studies have documented improvements in pain management and functional recovery associated with IoT-enabled implants; however, most have relied on quantitative measures and thus failed to capture the subjective dimensions revealed in this study. By applying Interpretative Phenomenological Analysis (IPA), the present research expands on prior literature by emphasizing personal meaning-making rather than merely functional effectiveness.

These results also support theories of technological embodiment, where individuals integrate medical devices into their sense of self (Mukhlis, 2025a; Mukhlis & Saidah, 2025). Consistent with earlier findings, participants described initial resistance followed by gradual acceptance, demonstrating how identity reconstruction occurs during recovery. Moreover, concerns about data privacy and control echo findings from studies on wearable health technologies, yet the present study contributes a richer understanding of the emotional weight patients attach to these concerns. Finally, the paradoxical coexistence of empowerment and dependence resonates with phenomenological perspectives on human-technology relations, offering insights into how technological mediation shapes both autonomy and vulnerability.

Through these connections, the study not only validates existing theories but also extends them by contextualizing patients' experiences within a technologically mediated healthcare environment. This interpretive depth underscores the value of phenomenology for exploring human-centered dimensions often overlooked in medical device research.

Implications of the Findings

The findings of this study provide both scientific insights and practical implications for healthcare practice and technological innovation. From a phenomenological perspective, patients' narratives reveal that adopting IoT-enabled smart implants is not merely a clinical intervention but also a socio-cultural experience involving identity, trust, and autonomy. These experiences highlight the need for healthcare providers to move beyond a purely biomedical perspective and adopt a patient-centered approach that acknowledges emotional, psychological, and cultural dimensions of recovery.

On a broader scale, the findings are relevant for shaping policy frameworks and technological designs that integrate data transparency, privacy protections, and psychological support for patients

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using connected medical devices. For clinical practitioners, understanding patients' subjective experiences can improve communication strategies, shared decision-making, and adherence to postoperative care plans. For device developers, the results underscore the importance of incorporating human-centered design principles that account for patients' emotional and social realities, rather than focusing solely on technical functionality. By integrating these insights, healthcare systems can better align technological innovation with the personal and cultural contexts of diverse patient populations.

Study Limitations

While this study offers valuable insights, several limitations should be acknowledged to ensure an appropriate interpretation of the findings (Hamberger et al., 2022; Iverson et al., 2019). First, the research was conducted within tertiary hospitals in a specific regional context, which may limit the transferability of results to other healthcare settings with different infrastructures or cultural norms. Second, the relatively small sample size a common feature in phenomenological research prioritizes depth over breadth, which restricts the ability to generalize findings to all patients using IoT-based implants.

Additionally, the study focused exclusively on patients' subjective experiences, without triangulating perspectives from healthcare providers or device developers. While this aligns with the phenomenological objective of capturing lived experiences, future studies incorporating multiple stakeholder viewpoints could provide a more comprehensive understanding. Finally, although the Interpretative Phenomenological Analysis (IPA) framework facilitated rich insights, its interpretive nature inherently involves researcher subjectivity, which should be considered when applying the findings to broader contexts.

Directions for Future Research

The present findings open several promising avenues for future research. First, expanding the study across different cultural and healthcare contexts would deepen understanding of how sociocultural factors influence patients' adaptation to medical IoT technologies. Comparative studies across regions or health systems could reveal significant variations in perceptions of trust, privacy, and technological embodiment.

Second, integrating perspectives from healthcare professionals, engineers, and policymakers could provide a more holistic framework for understanding how medical IoT technologies affect clinical practices and patient care models. Third, future studies could adopt longitudinal designs to explore how patients' perceptions evolve over extended recovery periods, offering insights into long-term adaptation and identity reconstruction. By extending the current research, future investigations can strengthen the development of patient-centered, ethically grounded, and culturally responsive innovations in medical device integration.

CONCLUSION

This study explored patients' lived experiences with IoT-enabled smart implants for postoperative pain management, addressing the need to understand the subjective meanings behind technologically mediated recovery. The findings revealed that while the devices enhanced physical recovery and improved quality of life, they also introduced challenges related to psychological adaptation, privacy concerns, and emotional dependence. By applying Interpretative Phenomenological Analysis (IPA), the study provides deeper insights into how patients perceive, internalize, and construct meaning around their interactions with smart medical technologies. These results address limitations in previous research by highlighting the human-centered dimensions of recovery that quantitative measures often overlook. The findings also offer practical implications for improving patient-centered care, guiding the development of more ethically grounded and culturally sensitive IoT-based medical devices. Future studies are encouraged to expand across diverse cultural and clinical contexts and explore long-term adaptation processes to strengthen understanding of human-device relationships in healthcare.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this article. The funding body, Ministry of Research, Technology, and Higher Education of the Republic of Indonesia (Kemenristekdikti), had no role in the design of the study, data collection, analysis, interpretation of results, or decision to publish this manuscript.

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