



Overcoming Challenges and Innovations in Orthopedic Prosthesis Design: An Interdisciplinary Perspective

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Abstract

Recent advances in the orthopedic prostheses design have significantly improved the quality of life for individuals with orthopedic disabilities. However, there are still critical challenges that need to be addressed to further enhance the functionality of orthopedic prostheses improving biocompatibility to promote better integration with natural tissues, enhancing durability to withstand the demands of daily use, and improving sensory feedback for better control of movement are the most pressing issues. To address these challenges, promising emerging solutions such as smart prosthetics, 3D printing, regenerative medicine, and artificial intelligence have been developed. These innovative technologies hold the potential to significantly enhance the functionality of orthopedic prostheses. Realizing the full potential of these next-generation orthopedic prostheses requires addressing several critical factors. These include interdisciplinary collaboration between experts in orthopedics, materials science, biology, and engineering, increased investment in research and development, standardization of components to ensure quality and reliability, and improved access to prosthetics. A comprehensive review of these challenges and considerations for future orthopedic prosthesis design is provided in this paper addressing the further advances to the field. By addressing these issues, we can continue to improve the lives of individuals with orthopedic disabilities and further enhance the field of orthopedic prosthetics.

Keywords Orthopedic prosthesis design · Biocompatibility · Durability · Sensory feedback · 3D printing · Regenerative medicine · Artificial intelligence

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Introduction

Orthopedic prostheses are medical devices that are designed to replace missing or damaged bones and joints, thereby restoring mobility and functionality to individuals with musculoskeletal injuries or conditions [1]. Over the years, advances in materials science and medical technology have led to the development of more sophisticated and functional orthopedic prostheses [2].

The use of orthopedic prostheses dates back to ancient civilizations, where evidence of prosthetic devices have been found in Egyptian mummies and Greek and Roman artifacts [3]. In the modern era, the development of orthopedic prostheses has been driven by a combination of medical and technological advancements, as well as increasing demand for these devices due to the growing global aging population [4]. The purpose of this clinical micro-review is to provide an overview of the most recent developments and advances in orthopedic prosthesis design [5]. The review will focus on

the background and history of orthopedic prostheses, as well as the current state of the field and the grand challenges of next generation orthopedic prosthesis design [6]. The review will be of interest to healthcare professionals, researchers, and individuals who are involved in the development and use of orthopedic prosthesis [7]. The information presented in this review will be useful for those who are seeking to gain a deeper understanding of the current state of the field and the challenges and opportunities for future development [8].

Overview of Current Orthopedic Prosthesis Design

Orthopedic prosthesis design involves the creation of medical devices that can be used to replace missing or damaged bones and joints [9]. The goal of orthopedic prosthesis design is to create devices that are durable,

functional, and flexible, while also being affordable and accessible to a wide range of applications based on individual's prosthesis requirements as shown in Fig. 1 [10]. In addition, Fig. 1 below describes five advanced orthopedic devices for lower limb replacement and augmentation, including a synthetic hip, multicomponent prosthesis, bionic foot, hybrid prosthesis, and bionic orthosis, which are designed to improve mobility and enhance the quality of life for patients with lower limb-related conditions.

To achieve this goal, orthopedic prosthesis designs must take into account a number of factors, including the type and location of the injury or condition, the age and overall health of the individual, and the individual's physical abilities and functional requirements [11]. The design process also involves the selection of materials and technologies that will provide the necessary strength and

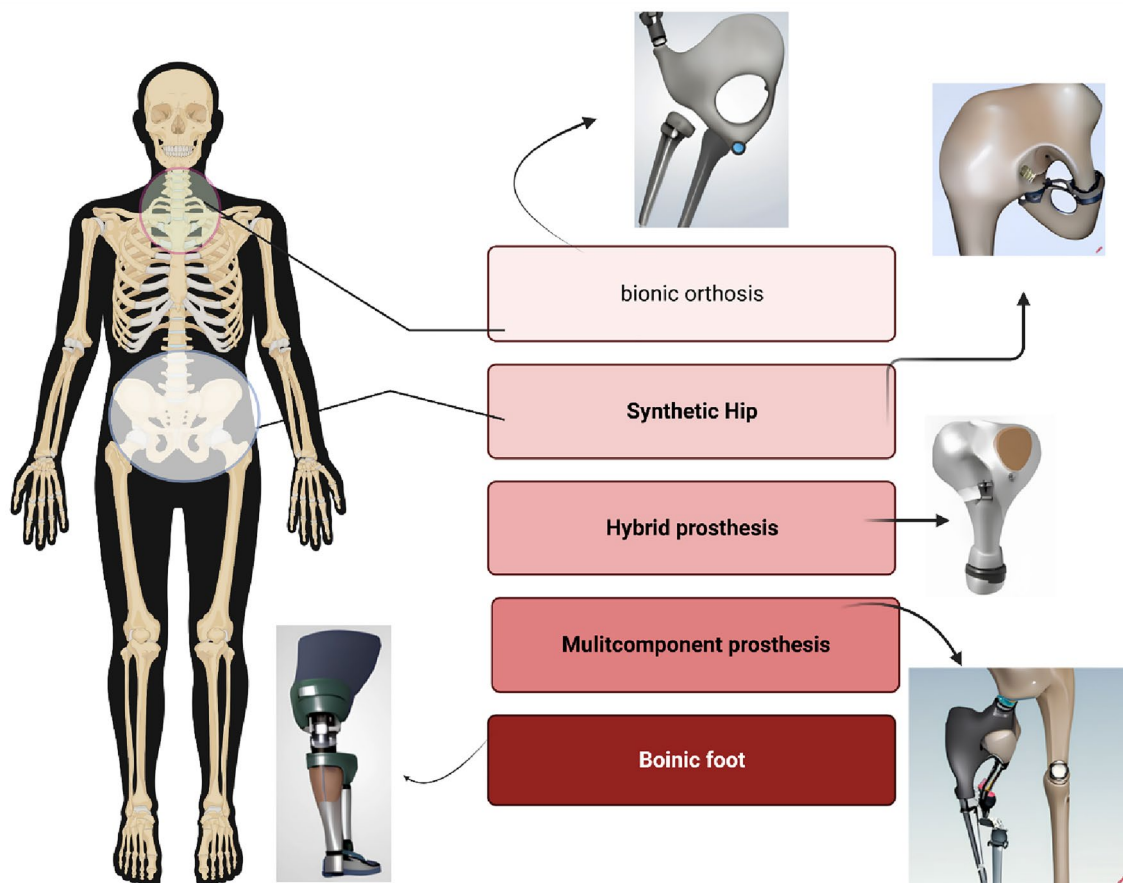


Fig. 1 Comparison of advanced orthopedic devices for lower limb replacement and augmentation. The figure shows five different types of advanced orthopedic devices: (a) Synthetic Hip, a prosthetic device used for total hip replacement; (b) Multicomponent Prosthesis, a modular implant that allows for customizable surgical solutions; (c) Bionic Foot, an advanced prosthetic device that mimics the natural movements and functions of a human foot; (d) Hybrid Prosthesis, a

combination of conventional and 3D-printed implant components for improved functionality and stability; and (e) Bionic Orthosis, a wearable device that utilizes advanced sensors and motors to augment human locomotion. These devices represent some of the latest advancements in orthopedics and are designed to improve mobility and enhance the quality of life for patients with lower limb-related conditions, whether through joint replacement or augmentation

durability while also being biocompatible with the body [12].

The current state of orthopedic prosthesis design is characterized by a growing body of research and development efforts aimed at improving the durability, comfort, and functionality of these devices [13]. This research is driven by the need to address the growing demand for orthopedic prostheses and the need to provide individuals with the highest quality of life possible [1]. The field of orthopedic prosthesis design is one that is rapidly evolving and offers exciting opportunities for the development of new and innovative devices [14]. This section of clinical technical aims to provide a comprehensive and brief overview of the current state of the field and the challenges and opportunities for future development [15]. Table 1 below gives a general overview of the key features, challenges, and opportunities in smart orthopedic prosthesis design. The specific challenges and opportunities may vary depending on the specific design goals and the target population for the prosthesis.

Current Status of Orthopedic Prosthesis Design

Advancements in Materials Science

One of the key areas of advancement in orthopedic prosthesis design is the development of new and advanced materials [16]. In recent years, there has been a growing interest in the use of biocompatible materials, such as titanium and carbon fiber, for the manufacture of orthopedic prostheses [17]. These materials provide a high degree of strength and durability, as well as being biocompatible with the body, which minimizes the risk of inflammation and rejection [18]. In addition to biocompatible materials, there has also

been a growing interest in the use of smart materials, such as shape memory alloys and piezoelectric materials, for the manufacture of orthopedic prostheses [18, 19]. These materials have the ability to change shape in response to changes in temperature or electrical current, which can be used to enhance the functionality of the prosthesis [20].

Improved Surgical Techniques

In addition to advancements in materials science, there has also been significant progress in the surgical techniques used for the implantation of orthopedic prostheses [21]. Minimally invasive surgical techniques, such as computer-assisted surgery and robot-assisted surgery, have become increasingly common, allowing for more precise and accurate implantation of prostheses [22].

These advances in surgical techniques have led to improved outcomes for patients, including faster recovery times, reduced pain and discomfort, and a lower risk of complications as shown in Fig. 2 about features of advanced orthopedic prosthesis [23]. In addition, Fig. 2 provides a visual representation of the key components that are revolutionizing the future of orthopedic prosthesis design. In particular, the figure highlights the importance of advanced biomaterials in enhancing compatibility, integration, durability, and functionality for superior patient outcomes. Additionally, the use of computer-assisted and robot-assisted techniques has allowed for the development of more sophisticated and customizable prosthesis designs, which can be tailored to the individual patient's needs and preferences [24].

Limitations of Current Designs

Despite the significant advances in orthopedic prosthesis design, there are still several limitations that need to be

Table 1 A summary of the key features, challenges, and opportunities in smart orthopedic prosthesis design

Key features of smart orthopedic prosthesis design	Challenges	Opportunities provided by biomedical engineering
Improved Durability and Longevity	High cost of materials and manufacturing processes	Development of advanced materials and manufacturing techniques for more cost-effective production
Comfortable and Customizable Fit	Difficulty in achieving a perfect fit for all users	Advancements in 3D printing [9] and scanning technologies for personalized prosthesis design
Functionality	Limited functionality compared to natural joints	Integration of advanced sensors and robotics technologies for improved functionality
Integration of Advanced Materials and Technologies	Challenges in achieving biocompatibility and integration with the body	Ongoing research in materials science and biomedicine for the development of advanced materials and technologies
Affordability and Accessibility	High cost of prostheses	Development of low-cost, mass-production techniques for more accessible prostheses



Fig. 2 Revolutionizing the future of orthopedic prosthesis: key components such as Advanced Biomaterials Enhance Compatibility, Integration, Durability, and Functionality for Superior Patient Outcomes

addressed [25]. One of the key challenges is the difficulty in achieving a comfortable and customizable fit for all patients. This is due to the wide variability in the anatomy and biomechanics of individual patients, which makes it difficult to design a prosthesis that is suitable for everyone [26]. Another challenge is the limited functionality

of current designs, compared to natural joints. Many orthopedic prostheses are still not capable of replicating the full range of motion and sensory feedback of natural joints, which can limit their effectiveness in restoring mobility and functionality to patients [27]. The field of orthopedic prosthesis design has made significant progress in recent years, with advances in materials science and surgical techniques leading to improved outcomes for patients. However, there are still several challenges that need to be addressed, including the difficulty in achieving a comfortable and customizable fit and the limited functionality of current designs [28].

Grand Challenges of Next Generation Orthopedic Prosthesis Design

Improved Biocompatibility and Opportunity Provided by 3D Printing for Advance Prosthesis Design

One of the biggest challenges facing the development of next-generation orthopedic prostheses is improving their biocompatibility with the human body [29]. This is critical for ensuring long-term success of the prosthesis and minimizing the risk of complications such as inflammation and rejection [28]. To achieve improved biocompatibility, researchers and engineers are exploring the use of new materials and surface treatments that are better tolerated by the body [30]. In addition, there is ongoing research into the development of advanced coating and surface modification techniques, such as the use of bioactive coatings, which can promote the integration of the

Table 2 Challenges and opportunities in modern prosthesis design

Challenge	Tools available	Important remarks	References
Improved Biocompatibility	Bioactive coatings, Surface modification techniques, Tissue engineering	Biocompatibility is crucial for the long-term success of prosthetics, as it can reduce the risk of infection, inflammation, and rejection	[3]
Enhanced Durability	Advanced materials, Multifunctional materials, Structural optimization	Durability is a critical factor in orthopedic prosthesis design, as it affects the longevity and reliability of the device [32]	[33]
Better Integration with Natural Bones and Tissues	Osseointegration, Tissue engineering, Regenerative medicine	Good integration with natural bones and tissues can improve the stability, function, and comfort of prosthetics	[34]
Advanced Sensory Feedback	Neural interfaces, Proprioception, Sensors	Sensory feedback can enhance the control, precision, and feedback from prosthetics, which can improve the overall user experience	[35]
Increased Functionality	Multi-articulating joints, Smart prosthetics, Artificial intelligence	Increased functionality can enhance the versatility and performance of prosthetics, making them better suited for different tasks and environments	[36]

prosthesis with the surrounding tissues and improve its biocompatibility [31]. Table 2 summarizes major challenges for advances orthopedic prosthesis design.

Enhanced Durability

Another key challenge in the development of next-generation orthopedic prostheses is improving their durability and longevity. This is critical for ensuring that the prosthesis is able to withstand the rigors of daily use over an extended period of time, and reducing the need for frequent replacements and revisions [37]. To achieve enhanced durability, researchers are exploring the use of advanced materials and manufacturing techniques, such as 3D printing and additive manufacturing depicted in Fig. 3 for advance bio-printing of prosthetic tissue [38]. These techniques allow for the production of prostheses with improved strength, durability, and biocompatibility, as well as the ability to tailor the design to the individual patient's needs and anatomy [39].

Better Integration with Bones and Tissues

A major challenge in the development of next-generation orthopedic prostheses is improving their integration with the surrounding natural bones and tissues [40]. This is critical for ensuring the long-term stability of the prosthesis, and for maximizing its functionality and restoring mobility to the patient [41]. To achieve better integration with natural bones and tissues, researchers are exploring the use of advanced surgical techniques, such as computer-assisted and robot-assisted surgery, 3D bioprinting (Fig. 3) which

allow for more precise and accurate production/implantation of the prosthesis. In addition, there is ongoing research into the development of new materials and surface treatments that promote the integration and osseointegration of the prosthesis with the surrounding bones and tissues [42].

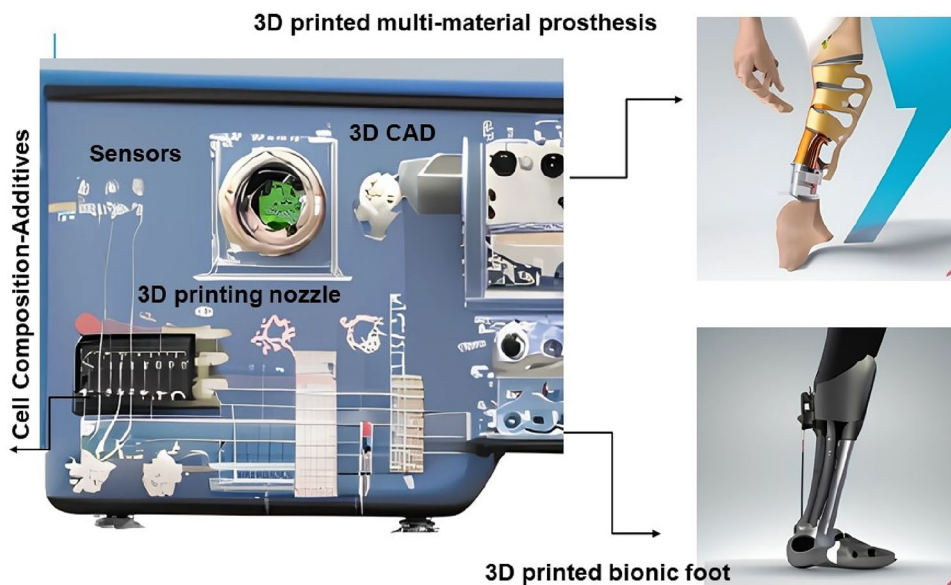
Advanced Sensory Feedback

Another key challenge in the development of next-generation orthopedic prostheses is improving their sensory feedback. This is critical for restoring the sense of touch and proprioception to the patient, which can improve the overall functionality of the prosthesis and enhance the patient's quality of life [43]. To achieve advanced sensory feedback, researchers are exploring the integration of advanced sensors and robotics technologies into the prosthesis design. These technologies can provide real-time feedback to the patient, allowing them to better control the movement of the prosthesis and improve their overall mobility and functionality [44].

Increased Functionality

Finally, a major challenge in the development of next-generation orthopedic prostheses is increasing their functionality, to more closely mimic the natural joint and restore mobility to the patient [33]. This requires the integration of advanced technologies and materials, such as robotics and shape memory alloys, which can improve the functionality and flexibility of the prosthesis [45]. 3D printing has revolutionized the field of prosthetics by providing a unique opportunity for advanced prosthesis design. With the ability to create precise and intricate

Fig. 3 Cell composition-additives and sensor integration in 3D-printed multi-material prosthesis with 3D CAD design



three-dimensional structures, 3D printing technology [46] allows for the customization of prosthetic devices to fit the unique needs of each individual patient [9]. This means that prosthesis can be designed with a higher level of accuracy, comfort, and functionality, leading to better outcomes and quality of life for the patients. Additionally, 3D printing offers a cost-effective and efficient way to produce prosthetic devices, making them more accessible to those who need them. Overall, the opportunities provided by 3D printing in the field of prosthetics are immense, and they have the potential to change the lives of countless individuals in need of prosthetic devices.

Drawbacks and Challenges of Artificial Intelligence in Orthopedic Prosthetic Design

One of the major drawbacks of AI in healthcare is bias. AI algorithms are only as good as the data they are trained on, and if the data is biased, the algorithm will be biased as well. This can lead to incorrect diagnoses or treatments, particularly for underrepresented populations. One potential solution to this problem is to develop more diverse and representative datasets for AI algorithms to be trained on. Additionally, researchers can implement bias checks and validation tests to ensure that AI algorithms are not perpetuating biases. Another drawback of AI in orthopedics is the lack of interpretability due to limited human related data. AI algorithms often work as a “black box”, meaning that it is difficult to understand how they arrive at their conclusions [47]. This can make it difficult for healthcare providers to trust the results and make informed decisions. One potential solution to this problem is to develop AI algorithms that are more transparent and interpretable. This can be achieved using explainable AI techniques that provide more insight into the decision-making process of the algorithm [48].

Privacy and security are also major concerns when it comes to AI in healthcare. Medical data is sensitive and should be protected from unauthorized access or use. One potential solution to this problem is to implement strong data privacy and security protocols that ensure the protection of patient data. Additionally, researchers can develop AI algorithms that are trained on encrypted data, which can help to protect patient privacy while still allowing for the development of accurate algorithms. Finally, there is the issue of the “human touch” in orthopedic research. While AI has the potential to improve efficiency and accuracy in healthcare, it cannot replace the empathy and compassion that healthcare providers add to human life. One potential solution to this problem is to integrate AI into healthcare workflows in a way that enhances, rather than replaces, the human touch [49]. For example, AI can be used to automate routine tasks, allowing healthcare providers to spend more

time with patients and provide more personalized care. In conclusion, the development of next-generation orthopedic prostheses presents a number of grand challenges, including improved biocompatibility, enhanced durability, better integration with natural bones and tissues, advanced sensory feedback, and increased functionality [50]. Addressing these challenges requires a multidisciplinary approach, including advances in materials science, surgical techniques, and robotics and sensory technologies [51]. Table 2 provides advanced key points for next generation smart prosthesis. The tools listed in this table are not exhaustive and there may be other solutions and technologies available for addressing the grand challenges of orthopedic prosthesis design, which are beyond scope to this technical paper [36]. The important remarks section highlights the key benefits and considerations of each challenge and the associated tools.

Future Directions for Orthopedic Prosthesis Design

Interdisciplinary Collaboration

Interdisciplinary collaboration is becoming increasingly important in the field of orthopedic prosthesis design [52]. By bringing together experts from various disciplines such as materials science, biomechanics, medicine, and engineering, it is possible to develop more effective solutions that address the complex challenges of orthopedic prosthesis design [53]. For example, collaborations between medical professionals, material scientists, and engineers can lead to the development of advanced materials that are more biocompatible and durable, as well as improved surgical techniques for attaching prosthetics to natural bones and tissues [54]. Interdisciplinary collaboration can also help to ensure that the latest advances in prosthetics research are translated into clinical practice more quickly, which can ultimately improve the quality of life for patients who rely on these devices [55].

Increased Investment in Research and Development

Increased investment in research and development is crucial for advancing the field of orthopedic prosthesis design [56]. This investment can support the development of new tools and technologies, as well as the testing and refinement of existing solutions. In addition, increased investment can help to attract and retain talented researchers and engineers who are working on developing the next generation of orthopedic prosthetics. This, in turn, can speed up the pace of innovation and lead to more effective solutions for patients who are in need of these devices [57].

Standardization of Prosthetic Components

Standardization of prosthetic components is important for ensuring that prosthetics are consistent, reliable, and interchangeable. Standardized components can make it easier for medical professionals to repair and replace prosthetics, and can also help to reduce the cost of these devices. By standardizing prosthetic components, it is possible to create a more efficient and streamlined supply chain, which can ultimately benefit patients who are in need of these devices [58].

Improved Access to Prosthetics

Improved access to prosthetics is crucial for ensuring that patients who are in need of these devices are able to receive them in a timely and affordable manner [59]. This can involve improving access to prosthetics through public health insurance programs, as well as making it easier for patients to obtain these devices through private insurance plans. In addition, improved access to prosthetics can involve increasing the number of medical professionals who are trained to prescribe and fit these devices, as well as increasing the availability of these devices in different parts of the world [10]. By improving access to prosthetics, it is possible to provide more people with the tools they need to lead more active and fulfilling lives [60].

Smart Prosthetics

Smart prosthetics are a rapidly emerging technology that incorporates sensors and advanced control systems to provide real-time feedback and personalized adjustments to the prosthetic. These advance bioinspired sensors which can mimic natural movements and provide information about the movement, position, and pressure on the prosthetic, allowing for better control and improved performance [14]. The advanced control systems can use this information to adjust the prosthetic in real-time to provide a more natural and personalized experience for the patient. Additionally, smart prosthetics can be designed to work with other devices, such as smartphones or tablets, allowing patients to adjust their prosthetic remotely or collect data on their prosthetic usage for later analysis. This technology holds tremendous promise for improving the functionality and usability of orthopedic prostheses.

Regenerative Medicine

Regenerative medicine is an exciting field that offers the potential for using natural tissue repair and regeneration to improve the biocompatibility of prostheses and potentially replace lost tissue [61]. This approach involves using cells,

growth factors, and biomaterials to stimulate the body's natural regenerative capacity to repair damaged tissues. For example, researchers have developed techniques for using synthetic biology, stem cells to generate new bone tissue, which could be used to support the integration of orthopedic prostheses with natural tissues [62]. Additionally, researchers are exploring the use of regenerative medicine to develop more biocompatible materials for use in orthopedic prostheses. By using regenerative medicine techniques, we can develop orthopedic prostheses that are more compatible with natural tissues, reducing the risk of complications and improving long-term outcomes for patients [63].

In conclusion, the future of orthopedic prosthesis design is likely to be shaped by interdisciplinary collaboration, increased investment in research and development, standardization of prosthetic components, and improved access to prosthetics. By addressing these challenges, it is possible to develop more effective solutions for patients who are in need of these devices, and ultimately improve the quality of life for people who rely on orthopedic prosthetics [34]. For example, sensory neuroprosthesis devices can improve the balance and stability of lower limb amputees during the Sensory Organization Test (SOT) as shown in Fig. 4. Figure 4 depicts the technology behind the neural interface and sensory neuroprosthesis for individuals with lower limb amputations. The figure illustrates the use of cuff electrodes that are implanted on nerves, which connect to an external stimulator. The external stimulator uses the cuff electrodes to detect pressure signals from the foot, which trigger electrical stimulation on the cuff contacts, creating sensations that match the pressure profile under the prosthetic foot. In addition, the figure highlights the use of Force Sensitive Resistors (FSRs) in an insole to detect pressure, which is used to trigger the electrical stimulation on the cuff contacts. The result is a sensory feedback mechanism that provides individuals with the sensation of a natural foot, allowing them to walk with greater confidence and control. The LL01 and LL02 references in the caption describe the reported sensations experienced by individuals who have used this technology. These individuals reported sensations in their missing toes and heels, which further highlights the potential of this technology to improve the quality of life for individuals with lower limb amputations. Overall, the neural interface and sensory neuroprosthesis are promising technologies that have the potential to significantly improve the functionality and mobility of individuals with lower limb amputations.

This device provides sensory feedback to the user, allowing them to adjust their posture and maintain balance more effectively.

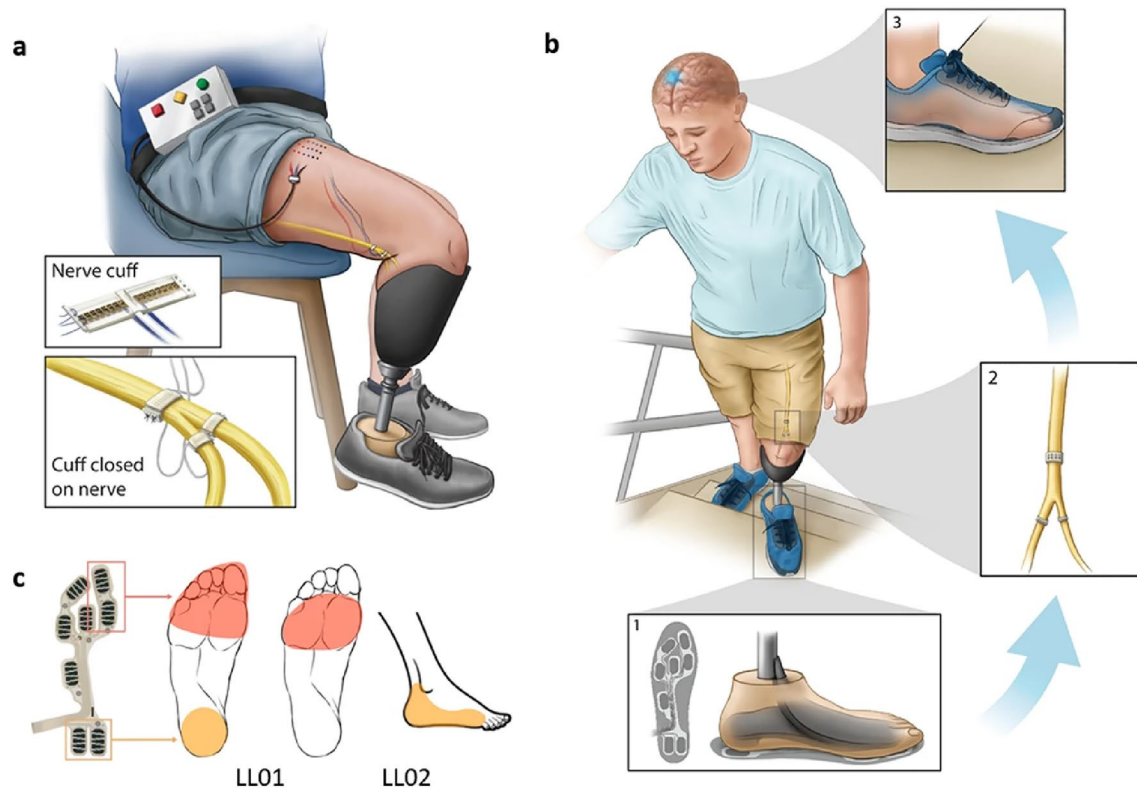


Fig. 4 Neural interface technology and the sensory neuroprosthesis. Cuff electrodes implanted on nerves connect to an external stimulator. FSRs in an insole detect pressure, which triggers electrical stimulation on cuff contacts, creating sensations matching the

pressure profile under the prosthetic foot. LL01 and LL02 reported sensations in missing toes and heels (*FSRs* force-sensing resistors, *LL* lower limb). Published with permission from [64] 2020 Springer-Nature

Recommendations for Future Research

The COVID-19 pandemic has had a significant impact on the healthcare system, including the field of orthopedics. While there is still much to learn about the virus and its impact on health, it is important to rely on accurate information and scientific evidence to inform our understanding of the pandemic and its effects [65, 66]. Many elective surgeries, including joint replacement procedures, were postponed or canceled to preserve hospital resources for COVID-19 patients. As a result, some patients may have experienced delays in receiving orthopedic prostheses. However, as healthcare systems begin to recover, orthopedic surgeons are working to address the backlog of patients in need of joint replacements and other orthopedic procedures. Advanced technologies and materials used in modern orthopedic prostheses, such as 3D printing and improved biocompatibility, are helping to enhance patient outcomes and reduce complications. Despite the challenges posed by the pandemic, the field of orthopedics remains committed to providing patients with the best possible care and treatment options. In order to continue to advance the field of orthopedic prosthesis design, it is important for researchers

and engineers to continue to focus on addressing the grand challenges that are facing this field. This can involve further development and refinement of existing tools and technologies, as well as the exploration of new solutions such as emerging applications of AI and machine learning [67, 68]. In addition, it is important for researchers to collaborate with medical professionals and patients to ensure that the latest advances in prosthetics research are translated into clinical practice in a timely and effective manner. By focusing on these recommendations, it is possible to continue to improve the quality of life for patients who rely on orthopedic prosthetics, and to provide them with the tools they need to lead more active and fulfilling lives [69].

The use of telehealth and remote monitoring technologies in orthopedic prosthetic design is another area of future research that has the potential to improve patient outcomes and reduce healthcare costs. In the future, advancements in telehealth and remote monitoring could enable healthcare providers to remotely monitor patients' prosthetic usage and adjust treatment plans as needed, improving patient outcomes and reducing healthcare costs. One direction for future research in telehealth and remote monitoring is the development of new technologies and platforms that are

specifically designed for orthopedic prosthetic patients. This could include the development of smartphone apps or wearable devices that enable patients to track their prosthetic usage and provide real-time feedback to their healthcare providers. Another area of future research is the development of machine learning algorithms and artificial intelligence models that can analyze large amounts of data from prosthetic sensors and other sources to identify patterns and trends in patient outcomes. This could enable healthcare providers to develop more personalized treatment plans that are tailored to the unique needs of individual patients. Finally, improving access to telehealth and remote monitoring technologies is crucial for realizing the full potential of these tools. This could include expanding broadband access in underserved areas and developing policies and reimbursement models that support the use of telehealth and remote monitoring in orthopedic prosthetic care. By addressing these challenges and focusing on these future directions, we can improve the accessibility and effectiveness of orthopedic prosthetic care and improve the lives of individuals with orthopedic disabilities.

Conclusion

The field of orthopedic prosthesis design is facing a number of grand challenges that must be addressed to improve the effectiveness and reliability of these devices [70]. These challenges include improved biocompatibility, enhanced durability, better integration with natural bones and tissues, advanced sensory feedback, and increased functionality. In order to address these challenges, a number of tools and technologies have been developed, including bioactive coatings, advanced materials, osseointegration, neural interfaces, and smart prosthetics [71]. By using these tools and technologies, it is possible to develop more effective solutions for patients who are in need of orthopedic prosthetics [72].

It is important to address the grand challenges of orthopedic prosthesis design is crucial for improving the quality of life for patients who rely on these devices [73]. By developing more biocompatible, durable, and functional prosthetics, it is possible to reduce the risk of complications, such as infection [65], inflammation, and rejection, and to improve the overall effectiveness and reliability of these devices. In addition, by integrating prosthetics more closely with natural bones and tissues, it is possible to improve the stability, function, and comfort of these devices, and to enhance the overall user experience [74]. By addressing the grand challenges of orthopedic prosthesis design, it is possible to provide patients with the tools they need to lead more active and fulfilling lives [75].

The integration of AI and machine learning (ML) in the field of orthopedic prosthesis design has the potential to revolutionize the way prosthetics are developed and used. AI can be used to analyze large amounts of data and make predictions about the behavior of prosthetics in real-world scenarios [76]. For example, ML algorithms can be used to predict how a prosthetic will behave under different loads, or to optimize the design of prosthetic components for improved biocompatibility, durability, and functionality [77]. In addition, AI and ML can be used to develop advanced control systems for prosthetics that can improve the user experience and provide enhanced sensory feedback. For example, AI-powered prosthetics can be designed to respond to the user's movements and provide real-time adjustments to optimize stability and comfort [78]. These advances can lead to more effective prosthetics that can be customized to meet the individual needs of each patient, and that can provide a more natural and seamless experience for users. Overall, the integration of AI and ML in the field of orthopedic prosthesis design has the potential to provide numerous benefits for patients, including improved functionality, better biocompatibility, enhanced durability, and better user experiences. By leveraging these advances in technology, it is possible to provide patients with the tools they need to lead more active and fulfilling lives.

Statistical Analysis

As a review article, our paper did not involve any original research data or experiments, and therefore no statistical analysis was conducted. We have updated the manuscript to include a statement to this effect in the experimental section, as requested by the journal.

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Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest Authors state no conflict of interests.

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