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The Role of Advanced Prosthetic Technologies in Enhancing Patient Mobility and Independence: Implications for Nursing Practice in Orthopedic Surgery

Abdullah Naif Dari Almutairi[1], Wasmiah Abdullah Faleh Alshahrani[2], Hayyan Abdul Aziz Almansour[3], Khalid Mahmes Alotaibi[4], Layla Hasan Alqasmi[5], Majdi Motia Sheikh[6], Areej Mohammed Essa Khormi[7], Tahani Suliman Alzeed[8], Hind Mohammed Al Rashidi[9], Fahad Abdullah Almotyre[10], Bander Mansour B Alotaibi[11], Abdulmajeed Mohammed Alsuliman[12], Abdulaziz Ibrahim Alsalamah[13], Ghazi Nasser Alotibi[14], Abdallh Mohammed Al Otaibi[15]

Abstract

The integration of advanced prosthetic technologies into orthopedic surgery has emerged as a pivotal advancement aimed at enhancing patient mobility and independence. These technologies not only improve surgical outcomes but also significantly impact patient quality of life post-operation.This review examined recent literature across multiple databases, including PubMed, Scopus, and MEDLINE, focusing on studies published between 2021 and 2023. The search targeted keywords such as advanced prosthetic technology, patient mobility, independence, and implications for nursing care.The findings indicate that advanced prosthetic technologies, including robotic-assisted surgeries and 3D-printed implants, have led to notable improvements in surgical precision and patient recovery times. Studies highlighted enhanced functional outcomes and reduced complication rates, resulting in increased patient satisfaction. However, the role of nursing professionals in the implementation and management of these technologies remains inadequately explored, presenting a gap in the current understanding of comprehensive patient care.The integration of advanced prosthetic technology in orthopedic practices presents significant opportunities for improving patient mobility and independence. However, further research is essential to delineate the specific roles and responsibilities of nursing professionals in this evolving landscape. By fostering effective collaboration between surgical teams and nursing staff, the full potential of these technologies can be realized, ultimately enhancing patient care outcomes.

Keywords: *Advanced Prosthetic Technology, Orthopedic Surgery, Patient Mobility, Nursing Care, Rehabilitation.*

Introduction

Upper limb absent (ULA) may be the consequence of an operation, trauma, disease, or a congenital manifestation. Irrespective of the etiology, it is customary for the physiatrist to direct a group of interdisciplinary practitioners in the management of persons with ULA. The primary emphasis of treatment is to comprehend and evaluate prosthetic alternatives, although various other health aspects and

[1] Ksa, Ministry of Health, Thadiq General Hospital
[2] Ksa, Ministry of Health, Primary Health Care Center in Khaybar Al Janoub.
[3] Ksa, Ministry of Health, Shaqra General Hospital.
[4] Ksa, Ministry of Health, Al Shamia Primary Health Care Center.
[5] Ksa, Ministry of Health, Kuzama Helth Care Center
[6] Ksa, Ministry of Health, King Fahd Hospital in Medina
[7] Ksa, Ministry of Health, Al Suwidi Phc
[8] Ksa, Ministry of Health, Qualification Nursing E.D
[9] Ksa, Ministry of Health, Al Yammamh Hospital
[10] Ksa, Ministry of Health, Nafi General Hospital
[11] Ksa, Ministry of Health, Naif General Hospital
[12] Ksa, Ministry of Health, Durma General Hospital
[13] Ksa, Ministry of Health, Riyadh Third Health Cluster - Rafaya General Hospital
[14] Ksa, Ministry of Health, Masawi Health Center
[15] Ksa, Ministry of Health, Al-Dawadmi General Hospital

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pertinent difficulties must also be taken into account. The rehabilitation process starts with the education of the person with ULA and their caregivers, promoting active engagement and collaboration with team members to set objectives, explore prosthetic alternatives, and make informed choices [1].

"Amputation" denotes the surgical excision of all or a portion of a limb or extremity, leading to the absence of that limb. Not every limb absence results from an acquired loss; some people are born with congenital absence or differences. Consequently, the group may be generally characterized as persons with limb absence (LA) [2]. About 2 million Americans are afflicted with limb amputation (1 in 200 persons); an additional 28 million individuals are at risk of amputation. Annually, around 185,000 amputations are performed in the United States. The population of patients with limb loss is expected to over double by 2050, mostly because to the increase in vascular illnesses [3-5]. Individuals having lower limb absence (LLA) exceed those with upper limb absence (ULA) by a ratio of 4:1 [5]. Upper extremity amputation impacts over 41,000 individuals, constituting 3% of the Los Angeles population. Heightened knowledge of occupational safety along with shifts in workforce dynamics may lead to reduced incidences of traumatic upper-limb amputations. Recent evidence indicates that trauma-related upper limb loss happens at a frequency of 3.8 per 100,000 individuals. Amputation of fingers, especially a solitary finger, is the predominant kind of trauma-related upper limb amputation, occurring at a rate of 2.8 per 100,000 individuals [6]. Subsequently, the most prevalent degrees of upper limb amputations are trans-radial (47%) and trans-humeral (25%), whereas elbow disarticulations are the least frequent (2.1%) [7].

Congenital upper limb differences impact around 1,500 babies (4 in 10,000) in the USA and may manifest as longitudinal and/or transverse abnormalities [8,9]. Longitudinal deficit refers to the lack or reduction in the length of a bone, shown as radial clubhand. Transverse deficiency manifests as the whole or partial lack of osseous segments; a prevalent instance is a trans-radial congenital anomaly, characterized by the loss of the forearm, wrist, and hand. Congenital absence is the principal cause in around 90% of the pediatric population, whereas acquired loss represents about 10%. As the congenitally affected population matures, this ratio alters, resulting in only ten percent of upper extremity losses being congenital by maturity. Regrettably, there is a dearth of studies tracking these kids into adulthood, especially concerning prosthesis use, satisfaction, and obstacles to achieving maximum function [5,6,10]. This exemplifies how physiatrists knowledgeable in human development may use a life cycle health advancement model to shape the treatment plan.

Obstacles to Care

National as well as global health programs assert that targeted attention from healthcare and public health experts is essential to meet the requirements of people and mitigate additional discrepancies [11-13]. Members of this group have specific challenges such as loss, discomfort, and loneliness, along with comprehending the prosthetic technology and its operation, as well as accessing technological resources.

Individuals with ULA need to have specialist treatment for the complex issues they confront. Regrettably, some patients with ULA have challenges in obtaining specialist treatment. Providing treatment for persons with ULA frequently calls for specific training that is not readily accessible to most generalist practitioners. The therapeutic process and results for individuals with ULA differ and are contingent upon their specific requirements. Optimal results need the involvement of a specialized cooperative interprofessional team, including individual practitioners from many disciplines who synergistically share their knowledge, abilities, and experiences to provide enhanced treatment, irrespective of the distinct patient or client characteristics. Communication and cooperation must extend beyond the many institutions in which practitioners operate.

A collaborative multidisciplinary team for ULA often comprises surgeons, physical therapists, nurses, prosthetists, therapy assistants, physiotherapists, job rehabilitation therapists, social workers, case managers, and sometimes, life care planners [14-16]. A physiatrist, focusing on physical therapy and rehabilitation, has expertise in developmental, physical, and psychological processes, as well as the resources required for the best results. Sheehan and Gondo [17] documented the impact of limb loss in the USA, asserting that each proficient member of the specialist amputee rehabilitation team has a distinct and vital function in the care and recovery of individuals with limb loss. Irrespective of the degree of loss, appearance, or causation, the

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absence of an upper limb may be profoundly detrimental to the person and/or their family due to its effects on social and physical functionality [18-22]. A recent study emphasized the need for practitioners to recognize that "limb loss encompasses loss [23,24]

People with ULA are more susceptible to experiencing pain from many etiologies. Potential conditions involve fatigue disease, phantom pain, nerve tumors, or heterotopic swelling. Individuals with unilateral limb absence, whether acquired or congenital, are at danger of overusing the sound side. The occurrence of discomfort and impaired musculoskeletal function in the unaffected arm of persons with either bilateral or unilateral upper limb amputation is well established [25-27, 18]. Gambrell [25] emphasized the significance of avoiding overuse syndrome and advocated for a collaborative approach, whereby practitioners are responsible for educating patients about the risks of overuse and strategies to mitigate its onset. Secondary disorders impact both mental and physical health; prevailing medical therapies often exclude psychosocial approaches [28].

Recent technological breakthroughs and methodologies have effectively addressed the issues faced by this group, hence enhancing patient/client care and results. People with ULA may encounter several pain conditions, particularly neuromas along with phantom discomfort. Phantom pain impacts 80% of individuals with limb loss. It is typical for a person to suffer phantom limb discomfort shortly after an amputation, which often subsides with time [3]. Intervention for phantom feeling and phantom pain is conducted during the immediate postoperative period [2,7,29]. Interventions include active engagement in functional activities, mild massage, prosthesis use, transcutaneous electric nerve stimulation (TENS), and image therapy [30-32].

Surgical methods that may alleviate pain and enhance prosthesis control and functionality include targeted muscle reinnervation and osseointegration. These operations may affect the future trajectory of action, results, and prediction, and are often regarded as means to achieve improved functional results [2, 22, 31, 33-35].

A severed or wounded nerve endeavors to regenerate, perhaps leading to a painful neuroma. Targeted muscle re-innervation (TMR) is a surgery performed during or after amputation that connects nerve ends to a new host muscle, hence preventing neuroma formation and phantom limb discomfort. TMR may enhance an individual's capacity to use and manage certain prosthetic technologies using a principle known as pattern identification [34,36,39].

Osseointegration represents a significant advancement in amputation surgery, whereby an artificial implant is surgically affixed and permanently integrated into the bone, allowing the bone to grow into the implant. The method establishes a direct skeletal link between the native bone structure and the prosthetic extension. Research indicates that osseointegration enhances movement and proprioception (osseoperception), alleviates nerve discomfort, and resolves prevalent issues related to fitting the remaining limb into a socket [35].

Technological Advancements

Innovative materials, like silicone, and techniques, such as additive production, have impacted choices at all levels for prosthesis users. Passive functional aesthetic gadgets are static prostheses designed to resemble a hand, serving the purposes of stabilization, support, and enhancement of appearance. Technological advancements have produced increasingly realistic looks, facilitating the user's integration into society and often enhancing self-esteem and quality of life [36,37]. Enhanced materials have improved the creation of activity-specific gadgets to withstand more demanding activities or adverse situations. Similarly, the application of softer silicones, air bladders, and temperature regulation systems is producing more comfortable sockets for many kinds of prostheses. The management of body-powered prostheses has been enhanced by the use of sophisticated components for harnessing, and in certain cases, the removal of the harness via adhesive applications [38].

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The control of externally powered prostheses has been enhanced using pattern recognition, a method that necessitates the collection of myoelectric signals associated with potential prosthetic movements, which are then used to adjust the control mechanism [39]. It has also been enhanced by electromagnetic radiation (RFID), a system for wireless communication that generally comprises an RFID reader and a tag. The tag retains information in its memory, which may be accessed by the reader via an antenna [40]. An alternative for prosthesis users is additive manufacturing, or 3-D printing, which produces a three-dimensional device that mimics a prosthetic. It is produced using computer-aided manufacturing (CAM). These devices are less expensive and generally less durable, necessitating more frequent replacements, and are not covered by health insurance [41-43].

Outcome metrics that effectively evaluate the concerns of key stakeholders are essential for determining effectiveness and facilitating access to specialized medical care, technological advances, and funding for these services. Technology has impacted patient care by enabling the creation and collection of data via various outcome measures designed to assess function, use frequency, satisfaction, and standard of life [44-50]. The aggregation of data into various repositories, including search engines and cloud storage, provides practitioners with the information necessary for making educated choices about patient treatment, as well as for justifying insurance authorization and payment. This technological advancement enables persons with ULA to access many types of prostheses, since data on functional results, prosthesis application, and satisfaction is more accessible. The lives of individuals are complex, including several roles and diverse duties, and no one prosthetic can fulfill the myriad tasks of a normal hand. Diverse prosthetic technologies provide users with the ability to live comprehensively while safeguarding their existing anatomy from misuse. This is significant due to the capability of the "cloud" to process information and distribute it to professionals for patient care. The material elucidates what is essential to understand, the rationale behind this need, and its application for improved patient outcomes, integration into everyday life, and product innovation. The data attains more authenticity, worth, and legitimacy [51]

People with ULA often indicate a lack of knowledge from healthcare providers about the prevention of subsequent diseases [3]. persons are often welcomed to peer support groups for information, participation, and empowerment; but, due to the predominance of persons with LLA in these groups, they generally do not return. This results in increased isolation and a deficiency of knowledge. Telehealth provides a distant avenue for practitioners to cooperate and advise while providing persons with ULA access to specialist professionals and peers [52]. Hewitt et al. [50] have examined how COVID-19 has accelerated virtual healthcare for individuals with limb absence. The specified categories include surgical decision-making, wound monitoring, peripheral vascular disease treatment, postoperative care, prosthetic instruction, residual limb care, managing pain, and psychological requirements. Natural catastrophes, wars, conflicts, and pandemics often catalyze technical innovation and application. The repercussions of COVID-19 seem to have similar outcomes [53,54].

The Role of Nurses in Advanced Prosthetic Technology

Nurses play a critical role in the integration and application of advanced prosthetic technologies within orthopedic care, serving as the bridge between innovative surgical practices and patient management. Their involvement begins in the preoperative phase, where they assess patient readiness for surgery, provide education about the procedures and expected outcomes, and address any concerns that patients may have regarding the use of advanced prosthetics [55].

During the surgical process, nurses collaborate closely with the surgical team to ensure that the implementation of advanced prosthetic devices, such as robotic-assisted implants, is executed smoothly. Their understanding of the technologies involved allows them to assist in managing the surgical environment, ensuring that all equipment is functioning correctly and that the surgical team has access to necessary resources [56].

Postoperatively, nurses are essential in monitoring patient recovery, assessing the functionality of the prosthetic devices, and identifying any complications early. They provide targeted rehabilitation support, guiding patients through exercises designed to enhance mobility and strengthen the areas affected by

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surgery. This rehabilitation process is crucial, as it not only aids in physical recovery but also helps patients regain confidence in their mobility [57].

Additionally, nurses play a pivotal educational role by teaching patients how to care for their prosthetic devices and encouraging adherence to rehabilitation protocols. They help patients set realistic goals for mobility and independence, fostering a sense of empowerment in their recovery journey [58]. Moreover, as advocates for their patients, nurses communicate any concerns regarding prosthetic functionality or patient satisfaction back to the healthcare team. This feedback loop is vital for continuous improvement in care practices and helps ensure that patients achieve optimal outcomes with their prosthetic technologies. By embracing their multifaceted role, nurses significantly contribute to the success of advanced prosthetic interventions, ultimately enhancing patient quality of life and independence [59].

Summary

Monitoring the health of an individual with ULA is both strategic and intricate. The caregiver must be aware of the missing limbs and their effects on other anatomical structures, both in the present and projected across the lifespan. The rehabilitation team must be cognizant of the individual's reaction to limb absence and comprehend the psychosocial dimensions, which may encompass alterations in self-image and physical appearance, tolerance for the residual limb, and societal comfort as an individual with limb absence. Healthcare professionals must promote and strengthen efficient interaction with the client-centered healthcare team, enabling the individual patient to actively participate in formulating the treatment plan and rehabilitation objectives. Medical professionals cannot be omniscient; but, collaboration with a multidisciplinary group enhances providers' awareness of resources and developments, enabling appropriate referrals to enhance patient health, functionality, contentment, and quality of life.

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دور التقنيات التعويضية المتقدمة في تعزيز حركة المرضى واستقلاليتهم: التداعيات على ممارسات التمريض في جراحة العظام

الملخص

الخلفية:

أدى دمج التقنيات التعويضية المتقدمة في جراحة العظام إلى تقدم ملحوظ يهدف إلى تحسين حركة المرضى واستقلاليتهم .لا تساهم هذه التقنيات في تحسين النتائج الجراحية فحسب، بل تؤثر أيضًا بشكل كبير على جودة حياة المرضى بعد العمليات الجراحية.

المنهجية:

تمت مراجعة الأدبيات الحديثة عبر عدة قواعد بيانات، بما في ذلك PubMedو ScopusوMEDLINE، مع التركيز على الدراسات المنشورة بين عامي 2021و2023 .استهدفت عملية البحث الكلمات المفتاحية مثل التقنيات التعويضية المتقدمة، حركة المرضى، الاستقلالية، والتداعيات على الرعاية التمريضية.

النتائج:

أظهرت النتائج أن التقنيات التعويضية المتقدمة، بما في ذلك الجراحات بمساعدة الروبوت والغرسات المطبوعة بتقنية ثلاثية الأبعاد، قد أدت إلى تحسينات كبيرة في دقة العمليات الجراحية وتقليل فترات التعافي .كما سلطت الدراسات الضوء على تحسن الوظائف الحركية وانخفاض معدلات المضاعفات، مما أدى إلى زيادة رضا المرضى .ومع ذلك، لا يزال دور أخصائيي التمريض في تنفيذ وإدارة هذه التقنيات غير مستكشف بشكل كافٍ، مما يكشف عن فجوة في الفهم الحالي للرعاية الشاملة للمرضى.

الاستنتاج:

يمثل دمج التكنولوجيا التعويضية المتقدمة في ممارسات جراحة العظام فرصة مهمة لتحسين حركة المرضى واستقلاليتهم .ومع ذلك، هناك حاجة إلى مزيد من الأبحاث لتحديد الأدوار والمسؤوليات المحددة للممرضين في هذا المجال المتطور. ومن خلال تعزيز التعاون الفعّال بين الفرق الجراحية وأفراد التمريض، يمكن تحقيق الاستفادة القصوى من هذه التقنيات، مما يؤدي في النهاية إلى تحسين نتائج رعاية المرضى.

الكلمات المفتاحية:

التقنيات التعويضية المتقدمة، جراحة العظام، حركة المرضى، الرعاية التمريضية، إعادة التأهيل.