

Advancements in Minimally Invasive Techniques for Joint Replacement in Orthopedic Surgery

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Abstract

Orthopedic joint replacement surgery has undergone a paradigm shift with the emergence of minimally invasive techniques. This paper explores the advancements in minimally invasive joint replacement, focusing on their definition, characteristics, and benefits. It delves into the role of innovative surgical instruments, advanced imaging and navigation technologies, and personalized treatment approaches in enhancing patient care. Furthermore, it discusses the clinical outcomes and patient-centered benefits of these procedures. The paper emphasizes their cost-effectiveness and accessibility, along with the challenges and future prospects, including surgeon training, economic considerations, and emerging trends in minimally invasive orthopedic surgery. These advancements have redefined the landscape of orthopedic surgery, prioritizing patient well-being, precision, and cost-efficiency.

Keywords: orthopedic surgery, joint replacement, minimally invasive techniques, surgical instruments, imaging technology, personalized treatment

1. Introduction

1.1 Background on Orthopedic Joint Replacement

Orthopedic joint replacement, a surgical procedure aimed at relieving pain and restoring function in individuals suffering from joint-related ailments, has witnessed a significant transformation over the years. Traditional joint replacement surgeries, while effective, often involve large incisions and extensive disruption of surrounding tissues. As a response to these limitations, minimally invasive techniques have emerged as a revolutionary approach in orthopedic surgery. These techniques are designed to achieve the same clinical outcomes as traditional procedures but with the added advantages of reduced tissue trauma, quicker recovery times, and lower complication rates.

Minimally invasive joint replacement focuses on the principles of minimal disruption, with smaller incisions and specialized instruments. This shift in approach has not only improved patient experiences but has also propelled the field of orthopedics into a new era of innovation and precision. It is essential to explore and understand these advancements in minimally invasive techniques for joint replacement, as they are at the forefront of improving patient outcomes and reshaping the landscape of orthopedic surgery.

This paper will delve into the intricacies of these innovative techniques, their clinical outcomes, challenges, and the potential they hold for the future of orthopedic joint replacement. By the end of this exploration, readers will gain a comprehensive understanding of the progress made in the field and the broader implications for orthopedic surgery.

1.2 Significance of Minimally Invasive Approaches

Minimally invasive approaches to joint replacement have gained significant significance in the field of

orthopedics for several compelling reasons. These approaches are at the forefront of transforming the way joint replacement surgeries are performed and have the potential to revolutionize patient care. The significance of minimally invasive approaches can be outlined as follows:

- 1) **Reduced Tissue Trauma:** One of the primary advantages of minimally invasive techniques is the minimization of tissue trauma. Traditional joint replacement surgeries often require large incisions, leading to substantial disruption of muscles and ligaments surrounding the joint. In contrast, minimally invasive approaches involve smaller incisions, leading to less tissue damage, reduced post-operative pain, and faster healing.
- 2) **Faster Recovery Times:** Patients undergoing minimally invasive joint replacement procedures typically experience shorter hospital stays and quicker post-operative recovery. This accelerated recovery process allows patients to return to their daily activities and regain their quality of life more rapidly.
- 3) **Lower Complication Rates:** Minimally invasive techniques are associated with a reduced risk of complications such as infections, blood loss, and scarring. The smaller incisions and precise surgical methods contribute to improved patient safety and overall outcomes.
- 4) **Enhanced Cosmetic Results:** Smaller incisions often lead to better cosmetic results, as they result in less visible scarring. This is not only important for the patient's self-esteem but also contributes to improved overall satisfaction with the procedure.
- 5) **Patient-Centered Care:** Minimally invasive approaches align with the growing trend of patient-centered care in modern medicine. Patients are increasingly seeking less invasive options that allow for faster recovery and improved quality of life, making these techniques more aligned with patient preferences.
- 6) **Innovation and Technological Advancements:** The adoption of minimally invasive techniques has driven innovation in surgical instruments, imaging technologies, and navigation systems. Surgeons and researchers continually seek ways to refine and improve these methods, leading to ongoing advancements in the field of orthopedic surgery.

The significance of minimally invasive approaches in orthopedic joint replacement cannot be overstated. These techniques offer a path to better patient outcomes, reduced healthcare costs, and a higher quality of care. This paper will explore the various aspects of these approaches, their outcomes, and their implications for the future of orthopedic surgery in greater detail.

2. Minimally Invasive Joint Replacement

2.1 Definition and Characteristics

Minimally invasive joint replacement, also known as minimally invasive surgery (MIS) in orthopedics, represents a paradigm shift from traditional open surgical procedures. This approach is defined by its distinctive characteristics, which set it apart from conventional methods.

Minimally invasive joint replacement is a surgical technique that aims to achieve the same clinical objectives as traditional joint replacement while minimizing surgical trauma to the patient. Its primary characteristics include the use of smaller incisions, which are strategically placed to access and replace the affected joint, resulting in reduced tissue disruption.

Furthermore, MIS techniques prioritize tissue preservation, meticulously safeguarding the integrity of surrounding muscles, ligaments, and tendons. Specialized instruments are employed, designed for precision and maneuverability within the confined space of smaller incisions. Advanced imaging technologies, such as fluoroscopy and intraoperative navigation systems, provide real-time visual guidance to the surgeon, enhancing surgical precision.

Tissue-sparing techniques, such as muscle-splitting or muscle-sparing approaches, are integral to MIS, minimizing trauma to the soft tissues adjacent to the joint. Increasingly, customization is a key feature, allowing surgeons to tailor the procedure to the patient's unique anatomy. This personalization ensures a more precise and patient-centric approach.

Furthermore, minimally invasive joint replacement often involves a collaborative effort among orthopedic surgeons, radiologists, anesthesiologists, and other healthcare professionals. This multidisciplinary approach optimizes patient care and outcomes.

By understanding these defining characteristics, we gain insight into the nuances of minimally invasive joint replacement. Collectively, these features contribute to reduced tissue trauma, expedited recovery, and improved patient outcomes associated with this surgical approach. As we delve further into this paper, we will explore the technological advancements and outcomes of minimally invasive techniques in greater detail.

2.2 Common Techniques in Minimally Invasive Surgery

Minimally invasive surgery in the realm of joint replacement encompasses several commonly employed techniques that have become integral to the field. These techniques have contributed significantly to the success and evolution of minimally invasive joint replacement procedures.

One of the primary techniques used in minimally invasive joint replacement is arthroscopy. Arthroscopy involves the use of small incisions to insert a camera and specialized instruments into the joint. This provides real-time visualization of the joint's interior, allowing the surgeon to assess and address issues with precision. Arthroscopy is particularly valuable for diagnosing and treating conditions such as torn ligaments, damaged cartilage, and joint inflammation.

Computer-assisted surgery, another common technique, utilizes advanced computer systems to enhance surgical precision. Surgeons can create 3D models of the patient's joint, enabling meticulous planning and accurate implant positioning. During the procedure, these systems provide real-time feedback and guidance, ensuring optimal implant placement.

Robotic-assisted surgery is an emerging technique that combines the expertise of the surgeon with the precision of robotic technology. Robots assist in performing the surgery, enhancing accuracy and reducing the margin of error. Surgeons can control the robotic system to execute precise movements, resulting in improved outcomes and shorter recovery times.

Navigation techniques, such as intraoperative navigation systems, provide real-time feedback to the surgeon throughout the procedure. These systems use advanced imaging and tracking technology to guide the surgeon's movements, enhancing precision and minimizing the risk of errors.

The common techniques in minimally invasive surgery described above have paved the way for greater precision, improved outcomes, and reduced patient recovery times. These techniques, in combination with the benefits of minimally invasive procedures, contribute to the transformation of joint replacement in orthopedic surgery. As we delve deeper into this paper, we will explore each of these techniques in more detail, highlighting their impact on patient care and surgical success.

3. Technological Advancements

3.1 Innovative Surgical Instruments

Technological advancements in minimally invasive joint replacement have ushered in a new era of precision and improved patient outcomes. Innovative surgical instruments play a central role in this progress, offering several noteworthy features that enhance the effectiveness and safety of these procedures.

These instruments are designed to complement the minimally invasive approach, with a focus on precision, maneuverability, and minimal tissue disruption. By understanding the significance of innovative surgical instruments in minimally invasive joint replacement, we can appreciate the strides made in enhancing patient care and surgical success.

Innovative surgical instruments include smaller, more specialized tools that allow surgeons to work through the smaller incisions characteristic of minimally invasive procedures. These instruments are meticulously crafted to facilitate precise movements and minimize disruption to surrounding tissues.

Furthermore, advancements in materials and manufacturing processes have contributed to the development of these instruments. High-quality, biocompatible materials are used to ensure the safety and compatibility of these tools within the human body. Additionally, some instruments may be custom-designed for specific procedures or tailored to individual patient anatomy.

These innovative instruments are at the forefront of enabling surgeons to perform complex joint replacement surgeries with greater accuracy and reliability. They are a testament to the ongoing commitment of the medical community to improve patient care, reduce complications, and enhance the overall quality of life for individuals undergoing joint replacement procedures.

As we delve further into this section, we will explore the impact of innovative surgical instruments on the field of minimally invasive joint replacement in greater detail, shedding light on the significant role they play in advancing orthopedic surgery.

3.2 Advanced Imaging and Navigation

Advanced imaging and navigation technologies have become integral components of minimally invasive joint replacement procedures, elevating the precision and effectiveness of these surgeries. These technologies provide real-time insights, guidance, and support to surgeons, making them indispensable in modern orthopedic surgery.

3.2.1 Advanced Imaging Technologies

One of the cornerstones of minimally invasive joint replacement is the utilization of advanced imaging

technologies. These include fluoroscopy, magnetic resonance imaging (MRI), and computed tomography (CT) scans. These imaging techniques enable preoperative planning by offering detailed visualizations of the patient's joint anatomy. Surgeons can identify pathology, assess bone quality, and accurately plan the procedure with the aid of these imaging modalities.

Intraoperative imaging, such as fluoroscopy, allows for real-time visualization during surgery. It provides continuous feedback on the placement of implants and helps ensure optimal alignment and positioning. This immediate feedback contributes to the accuracy and success of the surgical procedure.

3.2.2 Navigation Systems

Navigation systems are an essential component of minimally invasive joint replacement procedures. These systems use specialized tracking technology, including infrared cameras and sensors, to monitor the surgeon's movements and provide real-time guidance. By tracking the position and orientation of instruments and implants, navigation systems assist surgeons in achieving the desired surgical precision.

The benefits of advanced imaging and navigation technologies are substantial. They enhance the surgeon's ability to plan and execute the procedure accurately, leading to improved implant positioning, alignment, and overall success. These technologies reduce the margin of error, minimize complications, and contribute to better patient outcomes.

The integration of these advanced technologies has significantly impacted the field of minimally invasive joint replacement, making these procedures safer and more effective. As we delve further into this section, we will explore the various applications of these technologies in orthopedic surgery and their implications for the future of patient care.

3.3 Personalized Treatment Approaches

Personalized treatment approaches are a pivotal aspect of the advancements in minimally invasive joint replacement. These approaches cater to the unique needs of each patient, emphasizing individualized care and tailored surgical techniques. Such personalization represents a significant leap forward in the field of orthopedic surgery.

3.3.1 Customized Preoperative Planning

Personalized treatment begins with customized preoperative planning. Modern orthopedic surgeons have access to cutting-edge technology, allowing them to create 3D models of the patient's joint. These models provide an in-depth understanding of the patient's anatomy, enabling surgeons to plan the procedure with unparalleled precision. This level of customization ensures that the surgery is tailored to the patient's specific needs, optimizing the outcome.

3.3.2 Patient-Specific Implants

Personalized approaches often involve the use of patient-specific implants and prostheses. Advanced manufacturing techniques, such as 3D printing, have revolutionized the design and production of implants. These implants are custom-built to match the patient's unique joint anatomy, promoting a more precise fit and reducing the risk of complications. The result is improved long-term function and satisfaction for the patient.

3.3.3 Customized Surgical Techniques

Surgeons may also tailor their surgical techniques based on the patient's condition and requirements. This customization might involve adjusting the approach, implant placement, or other aspects of the procedure to address specific issues or challenges. Such flexibility ensures that the surgery is optimized for each individual, maximizing the chances of a successful outcome.

3.3.4 Enhanced Clinical Outcomes

The integration of personalized treatment approaches has translated into enhanced clinical outcomes and improved patient experiences. Patients undergoing personalized minimally invasive joint replacement tend to experience less pain, faster recovery, and a reduced risk of complications. This, in turn, contributes to higher satisfaction rates and a better quality of life.

Personalized treatment approaches represent a shift towards more patient-centric care in orthopedic surgery. By acknowledging and addressing the individual needs and characteristics of each patient, surgeons can achieve superior results and elevate the standards of joint replacement surgery.

As we delve further into this section, we will explore the impact of personalized treatment approaches on patient outcomes and the potential they hold for the future of orthopedic surgery.

4. Clinical Outcomes and Considerations

4.1 Efficacy and Comparative Studies

Evaluating the clinical efficacy of minimally invasive joint replacement techniques is essential for gaining insights into the impact of these procedures on patient outcomes. Comparative studies, which directly assess the effectiveness of minimally invasive approaches in comparison to traditional methods, offer valuable perspectives on the advantages and considerations of these surgical techniques.

Assessing the efficacy of minimally invasive joint replacement procedures involves a thorough examination of clinical outcomes. These outcomes encompass pain reduction, improved joint function, and overall patient satisfaction. A substantial body of evidence indicates that minimally invasive techniques consistently deliver outcomes that are either equivalent or superior to those achieved through traditional open surgery.

Comparative studies serve as a crucial tool for evaluating the benefits of minimally invasive approaches. These studies involve direct comparisons of patient outcomes and complications between minimally invasive surgery and conventional open surgery for joint replacement. The results consistently reveal that minimally invasive procedures are associated with shorter hospital stays, reduced post-operative pain, faster rehabilitation, and fewer complications.

Furthermore, comparative studies highlight lower infection rates and decreased blood loss associated with minimally invasive procedures. The reduced disruption to soft tissues and muscles often leads to more rapid patient recovery. Ultimately, these studies emphasize the clinical advantages of minimally invasive techniques and their potential to elevate the quality of patient care.

Long-term outcomes are also a significant consideration. Research studies tracking patient progress over several years consistently demonstrate that the clinical benefits, such as pain relief and improved joint function, endure over time. This underscores the durability and reliability of minimally invasive joint replacement as a viable and effective treatment option.

Patient satisfaction is a vital component of evaluating the efficacy of these procedures. A growing body of evidence indicates that patients who undergo minimally invasive joint replacement express higher satisfaction with their surgical experience, quality of life, and cosmetic results. Their overall contentment reflects the transformative impact of these techniques on patient well-being.

As we further explore this section, we will delve into the intricate details of these clinical outcomes and comparative studies, offering a comprehensive view of the concrete benefits of minimally invasive joint replacement in orthopedic surgery.

4.2 Patient-Centered Outcomes

Beyond the clinical efficacy of minimally invasive joint replacement procedures, the impact on the lives of patients cannot be overstated. Patient-centered outcomes shed light on the human aspect of these surgeries, revealing the profound difference they make in the overall well-being and quality of life of individuals undergoing such procedures.

At the heart of patient-centered outcomes lies the relief of pain and the restoration of joint function. Patients who opt for minimally invasive joint replacement often experience a significant reduction in pain, which has likely plagued them for years. This newfound pain relief enables them to regain control of their lives, partake in daily activities with ease, and once again find joy in movements that were previously excruciating.

Furthermore, the faster recovery times and shorter hospital stays associated with minimally invasive procedures mean less disruption to patients' lives. The reduced post-operative pain allows individuals to get back to their normal routines more swiftly. This, in turn, translates into an improved overall experience, as patients can promptly resume their daily activities and regain their independence.

The cosmetic aspect of these surgeries should not be overlooked. Minimally invasive procedures, with their smaller incisions, result in less noticeable scarring. This not only boosts patients' self-esteem but also contributes to a more positive surgical experience. Patients often appreciate not only the functional improvements but also the aesthetic aspect of their results.

Patient-centered outcomes extend beyond the physical realm to encompass the broader aspects of quality of life. Patients who undergo minimally invasive joint replacement find their overall well-being enhanced, and their satisfaction with life elevated. The ability to return to hobbies, work, and social activities, free from pain and with improved joint function, significantly contributes to their happiness and life fulfillment.

Another compelling aspect is the lower incidence of complications associated with minimally invasive procedures. Reduced risks of infections, blood loss, and other post-operative issues contribute to a safer and more positive surgical experience. Patients can rest assured that their procedure is not only successful but also marked by a lower risk of unforeseen complications.

The collective impact of minimally invasive joint replacement on patients' lives has led to high levels of

satisfaction. Individuals undergoing these procedures often express greater contentment with their surgical experiences, recognizing the improvements in their quality of life as a testament to the transformative effect of these patient-centric surgical approaches. Patient-centered outcomes emphasize the significance of not only clinical success but also the profound difference these procedures make in the lives of those suffering from joint-related issues.

4.3 Cost-Effectiveness and Accessibility

The benefits of minimally invasive joint replacement extend beyond clinical outcomes and patient satisfaction. They also have significant implications for the cost-effectiveness and accessibility of orthopedic surgeries.

Minimally invasive procedures often prove to be more cost-effective in the long run. While the initial equipment and training costs might be marginally higher, the shorter hospital stays and quicker post-operative recoveries translate into reduced healthcare expenditures. These procedures reduce the burden on healthcare resources and minimize the economic impact on patients and healthcare systems.

Additionally, the overall cost-effectiveness of minimally invasive joint replacement extends to the reduced need for post-operative rehabilitation and therapy. Patients who undergo these procedures typically require less post-operative care, resulting in savings for both individuals and the healthcare system.

The shorter recovery times also mean that patients can return to work and resume their daily lives more swiftly. This contributes to the preservation of their earning capacity and quality of life, further enhancing the cost-effectiveness of these procedures.

Accessibility is another vital consideration. Minimally invasive joint replacement procedures are often more accessible to a broader patient population. The reduced length of hospitalization and post-operative care requirements means that healthcare facilities can accommodate more patients in need of joint replacement surgeries. This increased accessibility addresses the growing demand for such procedures, making them available to a wider demographic.

Minimally invasive approaches align with the evolving trend in healthcare toward more efficient and accessible care. By offering cost-effective solutions and improving accessibility, these procedures contribute to better patient care and the overall sustainability of healthcare systems.

As we explore this section further, we will delve into the economic considerations and the impact of minimally invasive joint replacement on healthcare accessibility, emphasizing the role these procedures play in reshaping the orthopedic surgery landscape.

5. Challenges and Future Prospects

Orthopedic joint replacement surgery has witnessed remarkable advancements in minimally invasive techniques. However, as we look ahead, we must acknowledge the challenges that still persist and the promising future prospects in this field.

5.1 Surgeon Training and Skill Development

One of the foremost challenges in the domain of minimally invasive joint replacement lies in surgeon training and skill development. Mastering these advanced techniques demands specialized training, mentorship, and substantial hands-on experience. Surgeons need to become proficient in using innovative instruments, navigating advanced imaging systems, and adapting to patient-specific approaches. The commitment to surgeon education is essential to ensure the safe and effective implementation of minimally invasive procedures.

5.2 Economic and Accessible Healthcare

While minimally invasive procedures offer cost-effective advantages, economic considerations are still a challenge. Initial investments in technology and training can be a barrier for healthcare facilities, and the long-term cost savings might not be immediately evident to some stakeholders. Ensuring the financial viability and accessibility of these procedures for all patients remains a significant challenge. Addressing this challenge requires a thoughtful approach to healthcare policy and reimbursement structures to promote wider adoption.

5.3 Emerging Trends in Minimally Invasive Orthopedic Surgery

The future of minimally invasive orthopedic surgery is filled with promising trends. Emerging technologies, such as augmented reality and artificial intelligence, hold potential for even greater precision and improved patient outcomes. Robotic-assisted surgeries are likely to become more commonplace, further enhancing surgical accuracy and safety. Moreover, the continued development of patient-specific implants and surgical approaches will ensure a personalized experience for each patient.

Furthermore, minimally invasive approaches are extending their reach to a broader range of orthopedic conditions, not limited to joint replacement. They are being applied to the treatment of fractures, spine

conditions, and soft tissue injuries. This expansion broadens the scope of minimally invasive orthopedics and offers new avenues for improving patient care.

As we navigate the challenges and embrace the future prospects, it is evident that minimally invasive orthopedic surgery is poised for continued growth and transformation. By addressing training needs, ensuring economic viability, and staying at the forefront of emerging trends, this field will continue to enhance patient care and redefine the landscape of orthopedic surgery.

6. Conclusion

The evolution of minimally invasive techniques in orthopedic joint replacement surgery has ushered in a new era of patient-centric care, precision, and cost-effectiveness. This journey through the landscape of minimally invasive joint replacement has revealed not only the significant progress but also the challenges and future prospects in this transformative field.

The significance of minimally invasive approaches cannot be overstated. These techniques have redefined the landscape of joint replacement surgery by minimizing tissue trauma, enhancing patient outcomes, and reducing healthcare costs. They prioritize the well-being of patients, emphasizing faster recovery, reduced complications, and improved quality of life. With smaller incisions, innovative surgical instruments, advanced imaging technologies, and patient-specific approaches, minimally invasive techniques offer a path to better patient care and outcomes.

Challenges such as surgeon training and skill development, and ensuring economic viability and accessibility, remain on the horizon. Surgeon education and skill mastery are vital to maximize the potential of minimally invasive procedures. Economic considerations need to be addressed to ensure that these advanced techniques are accessible to all patients in need.

As we peer into the future, we find that the trends in minimally invasive orthopedic surgery are filled with promise. Emerging technologies, from augmented reality to robotics, are poised to enhance precision and safety. The development of patient-specific implants and approaches will continue to personalize the patient experience. Moreover, the scope of minimally invasive orthopedics is expanding beyond joint replacement to encompass fractures, spine conditions, and soft tissue injuries, broadening the possibilities for improved patient care.

In conclusion, the journey through the advancements in minimally invasive techniques for joint replacement in orthopedic surgery highlights a transformative landscape. It is a landscape where patient well-being, precision, and cost-effectiveness are at the forefront. As we navigate the challenges and embrace the future prospects, it is evident that this field is poised for continued growth and transformation, promising a brighter future for patients in need of joint replacement surgeries.

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