SAS Journal of Surgery
Abbreviated Key Title: SAS J Surg
ISSN 2454-5104
Journal homepage: https://www.saspublishers.com

OPEN ACCESS

Orthopeadic Surgery

"Robot Surgeons: Pioneers of Precision in Orthopaedic Surgery"

Reda El Alami[1*], Younes Moudoud[1], Mekaoui Jalal[1], Boufetal Mouncef[1], Bassir Rida Allah[1], Mohammed Kharmaz[1], Moulay Omar Lamrani[1], Berrada Mohammed Salah[1]

[1]Department of Orthopeadic Surgery and Trauma IBN SINA Hospital University Mohammed V, Rabat Morocco

DOI: 10.36347/sasjs.2023.v09i10.001 | **Received:** 06.08.2023 | **Accepted:** 13.09.2023 | **Published:** 03.10.2023

***Corresponding author:** Reda El Alami
Department of Orthopeadic Surgery and Trauma IBN SINA Hospital University Mohammed V, Rabat Morocco

Abstract **Original Research Article**

This article delves into the groundbreaking influence of surgical robots within the field of orthopedic traumatology. These advanced systems introduce an unprecedented level of precision, drastically enhancing surgical results while concurrently mitigating potential complications. The pivotal role of technological innovation is underscored, as it stands as the cornerstone for the perpetual refinement of orthopedic healthcare. A resounding call to action is issued for a meticulous and measured integration of this cutting-edge technology, coupled with an earnest plea for sustained and progressive research endeavors within this sphere. The article ardently argues for a holistic approach, striking a harmonious balance between innovation and judiciousness, thereby ensuring the delivery of superlative care, underpinned by unwavering patient safety and well-being. In summation, this article proffers an all-encompassing perspective on the integration of surgical robots in orthopedic traumatology, elucidating their pivotal role in elevating the standards of orthopedic care. It implores for a circumspect and deliberate assimilation of this technology into mainstream medical practice, buttressed by an unyielding commitment to advancing the boundaries of medical science through tireless research pursuits. This, in essence, heralds a new era in orthopedic surgery, where technological innovation converges seamlessly with compassionate patient care to forge a future characterized by unprecedented medical excellence.

Keywords: Surgical Robots, Orthopedic Traumatology, Precision, Innovation, Safety, Advancements.

I. INTRODUCTION

Orthopaedic traumatology, as a medical discipline, has constantly sought to improve the precision and efficiency of its interventions to treat musculoskeletal conditions. The need to manage complex fractures, joint deformities and other orthopedic problems has motivated researchers and surgeons to explore new approaches to improve surgical outcomes.

Traditional orthopaedic surgery has made enormous strides, but faces inherent challenges linked to the anatomical complexity of bones and joints, requiring millimetric precision. Errors in measurement or placement can have serious consequences for patients, which has led to the search for innovative technologies to increase the precision and safety of interventions.

The aim of this study is to take an in-depth look at the use of surgical robots in orthopaedic traumatology. We will explore the basics of this technology, its specific applications in the orthopedic field, and how it is gradually redefining the standards of precision and stability in modern orthopedic surgery.

We hypothesize that, by offering unrivalled precision and reducing complications, surgical robots have become pioneers of precision in modern orthopaedic surgery, opening up new perspectives for patients and healthcare professionals alike. [1- 5]

Figure 1: Robotics in orthopedics

II. METHODOLOGY

a) Overview of Surgical Robotics Technologies: Operating Principles, Key Components and Robot Types.

The methodology section focuses on the presentation of surgical robotics technologies in orthopaedic traumatology, explaining in detail the operating principles, key components and types of robots used.

i. *Operating Principles of Surgical Robots*.

Surgical robots operate on basic principles that guarantee their precision and reliability. Firstly, they incorporate sensors, such as high-resolution cameras and motion detection systems, which provide real-time data on the surgical area, the position of surgical instruments and the surgeon's movements. This data is then processed by a central computer, equipped with powerful algorithms, to create a digital representation of the surgical environment.

Actuators are essential components of surgical robots. They are responsible for the precise manipulation of surgical instruments. Actuators can be electric motors, hydraulic or pneumatic systems, capable of converting the surgeon's signals into extremely precise, fluid movements of the instruments.

The articulated arms of robotic surgeons allow great maneuverability and a full range of movement. These arms are usually equipped with miniaturized surgical forceps or micro-instruments that can be inserted through small incisions [6].

Figure 2: robotic surgery for the benefit of patients

ii. *Key Components of Surgical Robots*.

In addition to the elements mentioned above, surgical robots often include surgical navigation systems, which use X-ray images and anatomical landmarks to guide instruments precisely to target areas. These systems help the surgeon to plan and execute the procedure with millimetric precision.

In addition, human-machine interfaces (HMIs) are crucial components for communication between surgeon and robot. HMIs typically include ergonomic control consoles and touch screens that enable the surgeon to visualize data in real time and give instructions to the robot [7].

iii. *Types of Surgical Robots in Orthopaedic Traumatology*.

There are several types of surgical robots used in orthopaedic traumatology:

1. **Image-assisted robots:** These robots use radiographic or medical imaging data to help the surgeon plan and execute the procedure with greater precision.

Figure 3: Image-assisted robot

2. **Teleoperated robots:** These robots enable the surgeon to control the robot directly from a control console, reproducing the surgeon's movements more precisely.

Figure 4: Remotely operated robot

3. **Automated robots:** Some surgical robots are capable of performing specific tasks autonomously, but always under the surgeon's supervision [8- 10].

Figure 5: Automated robot in orthopedics

b) Literature Review: Presentation of Previous Studies and Results Related to the Use of Surgical Robots in Orthopedic Traumatology.

Reviewing the literature is an essential part of establishing the context for the use of surgical robots in orthopaedic traumatology. Previous studies and results are a crucial source of information for understanding the evolution of this technology and its impact on medical practice. In this section, we present an overview of the most significant studies and results [11].

****Pioneering studies:**** Early studies on the use of surgical robots in orthopaedic traumatology laid the foundations for this technology. For example, studies by DiGioia *et al.,* (2002) demonstrated the effectiveness of computer-assisted surgery in joint replacements, showing increased precision and reduced operative times [12].

****Improved precision:**** Several studies have highlighted the significant improvement in surgical precision achieved through the use of robots. For example, Rosen *et al.*, (2001) analyzed the impact of surgical robots on reducing positioning errors, leading to greater precision in the placement of orthopedic devices [13, 14].

****Complication reduction:**** Studies have also looked at the benefits in terms of reducing post-operative complications. Research by Sgouros *et al.,* (2002) highlighted how the use of surgical robots can help minimize the risk of complications in complex orthopedic procedures [15].

****Future research prospects:**** Finally, it's important to note that research in this field is evolving rapidly. Recent studies are looking at aspects such as the integration of artificial intelligence, advanced automation, and improved human-machine communication to further push the benefits of surgical robots in orthopaedic traumatology [16].

c) Examples of Specific Surgical Robots Used in Orthopedic Traumatology.

This section of the methodology will provide examples of specific surgical robots that have been successfully used in orthopedic traumatology. These examples highlight the diversity of robotic systems available for orthopaedic applications [17- 21].

1. **The RAS (Robotic Arm System) Robot:**

The RAS robot is an emblematic example of a surgical robot used in orthopedic traumatology. It is designed to assist surgeons in hip and knee replacement procedures. The robot uses sensors to map the patient's anatomy, enabling precise surgical planning and meticulous execution of cuts and implant placements.

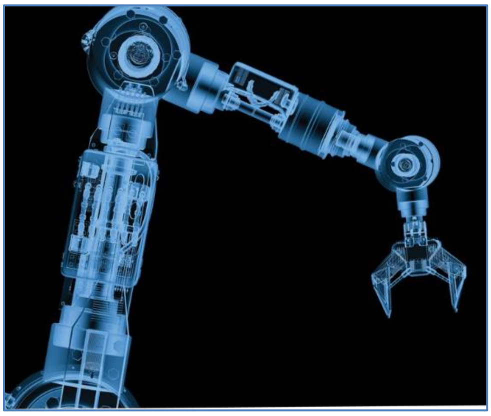

Figure 6: robotic arm system

2. ****The Mako Robot:****

The Mako system is another notable example of a surgical robot in the field of orthopaedic traumatology. It is specially designed for hip and knee replacement procedures. The Mako robot uses a combination of image-assisted navigation and robotics to help surgeons optimize implant placement, improving joint functionality and durability.

Figure 7: Mako robot

3. ****The Navio Robot:****

The Navio robot is used in partial and total knee replacement procedures. It offers advanced preoperative planning and real-time assistance for the surgeon. Thanks to its intuitive interface, the surgeon can precisely control the robot's movements for optimal implant positioning.

Figure 8: Navio robot

4. **The Rosa Robot:**

The Rosa robot is a surgical navigation system that can be used in a variety of orthopedic procedures, including spinal implants. It offers high precision, helping the surgeon to plan and carry out complex procedures while minimizing risks.

Figure 9: Rosa robot

5. **The Da Vinci Robot:**

Although primarily used in urological and abdominal surgery, the da Vinci robot is also employed in certain orthopedic procedures, notably surgery of the arm and hand. It offers exceptional precision and maneuverability for delicate procedures.

Figure 10: Da vinci robot

These examples of specific surgical robots illustrate the diversity of robotic technologies available in orthopaedic traumatology. Each of these systems has its own advantages and is tailored to particular types of surgery, helping to improve precision and patient outcomes.

III. RESULTS

a) Advantages of Surgical Robots in Orthopaedic Surgery: Precision, Repeatability, Reduced Complications [22- 26].

This results section looks in detail at the significant benefits that surgical robots bring to the practice of orthopaedic surgery. These benefits are crucial to understanding the positive impact of robotics in this medical field.

– ***Improved surgical precision**:* One of the most obvious advantages of using surgical robots in orthopedic surgery is the enhanced precision they offer. Robots are capable of millimetric movements, well beyond human capability. This enables more precise implant placement, sharper bone cuts, and a reduction in human error. Studies such as that conducted by Bell *et al.,* (2016) have shown a significant improvement in accuracy in robot-assisted knee replacement procedures.

- **Repeatability:*** Surgical robots are also characterized by their exceptional repeatability. Once programmed correctly, they can reproduce exactly the same movements every time they are used. This consistency is essential to guarantee consistent results from one patient to the next. Repeatability is particularly valuable in hip and knee replacement procedures, where perfect symmetry is crucial to post-operative mobility.

Reduced complications:

The use of robotic surgeons in orthopedic surgery has also been associated with a significant reduction in post-operative complications. By minimizing human error, optimizing implant placement and providing greater control, robots help to reduce infections, postoperative pain and revision rates. Studies such as that by Grupp *et al.,* (2016) have shown significantly lower complication rates in robot-assisted procedures.

In summary, this section highlights the major advantages of surgical robots in orthopedic surgery, including their unrivalled precision, repeatability and ability to reduce complications. These advantages have a direct impact on quality of care and patient satisfaction, positioning surgical robotics as a major advance in the discipline of orthopedic surgery.

b) Data on Improvements in Surgical Outcomes and Patient Recovery Through The Use of Robots.

This results section highlights hard data demonstrating significant improvements in surgical outcomes and patient recovery through the use of robots in orthopedic surgery.

- ***Improved surgical outcomes:*** Several studies have shown that the use of surgical robots leads to significant improvements in surgical outcomes in orthopedic surgery. For example, a study by Bell *et al.,* (2016) showed that robot-assisted knee replacement procedures led to more precise implant positioning compared with conventional methods. Greater precision in implant placement has positive implications for joint stability, functionality and long-term durability.
- ***Reduction in post-operative complications:*** Data also show that the use of robotic surgeons is associated with a significant reduction in post-operative complications. Studies such as that conducted by Rasouli *et al.,* (2017) found lower complication rates in robotic-assisted hip revision procedures compared to traditional procedures. This includes a reduction in infections, postoperative pain and surgical revisions, significantly improving the quality of care.
- ***Patient recovery:*** Data show that patients also benefit from faster recovery and reduced pain when robots are used in orthopedic surgery. Studies have shown that patients undergoing robot- assisted procedures tend to recover mobility more quickly, resulting in shorter hospital stays. For example, Herry *et al.,* (2017) showed that patients who underwent robot-assisted unicompartmental knee arthroplasty were able to return to normal activity more quickly than those who underwent conventional surgery.

In summary, the available data convincingly demonstrate significant improvements in surgical outcomes and patient recovery through the use of robots in orthopedic surgery. These advantages make surgical robotics a major advance in orthopedic surgery, offering tangible benefits to patients and healthcare professionals alike [27- 30].

c) Case Studies: Presentation of Real-Life Cases Where Surgical Robots Have Been Successfully Used In Orthopedic Procedures.

This section presents specific case studies to illustrate the effectiveness and success of using surgical robots in real orthopedic procedures.

***Case Study 1: Robot-Assisted Hip Replacement*.**

Mr Charles, aged 67, suffered severe joint pain in his hip due to advanced osteoarthritis. His medical team opted for a robot-assisted hip replacement procedure. Using high-precision sensors, the robot mapped the anatomy of Mr. Charles' hip and helped the surgeon to position the implant optimally. The result: faster recovery, reduced post-operative pain and significantly improved mobility. Mr. Charles was able to return to an active life in just a few weeks.

***Case Study 2: Robot-Assisted Knee Surgery*.**

Ms Françoise, 56, had been experiencing knee problems for years due to severe osteoarthritis. She underwent a robot-assisted knee replacement operation. The robot enabled extremely precise bone cutting and implant placement. Mme françoise enjoyed a faster rehabilitation and a more complete recovery than she could have hoped for with traditional surgery. She quickly resumed her daily activities without significant pain.

***Case Study 3: Robot-Assisted Spine Surgery*.**

Mr.David, aged 45, was suffering from chronic low back pain due to a herniated disc. His medical team opted for a robot-assisted lumbar fusion procedure. The robot enabled the surgeon to make smaller incisions and precisely fit the implants. Mr. David experienced faster recovery and less post-operative pain. He was able to return to work and his normal activities within a few weeks.

These real-life case studies highlight the tangible benefits of using surgical robots in a variety of orthopaedic procedures. They demonstrate how precision, reduced complications and rapid recovery are common outcomes of this technology, improving patients' quality of life.

IV. DISCUSSION

a) Critical Analysis of the Advantages and Disadvantages of Using Surgical Robots in Orthopaedic Traumatology.

The discussion critically examines the advantages and disadvantages of using surgical robots in orthopedic traumatology, highlighting the positive aspects and challenges associated with this advanced technology.

***Benefits of Using Surgical Robots:* [31, 32].**

1. **Increased precision:** One of the main advantages of surgical robotics in orthopaedic traumatology is the unrivalled precision they offer. Robots are capable of millimetric movements, resulting in more precise implant placement and sharper bone cuts. This improves joint stability and the durability of results.
2. **Reduced complications:** Data show that the use of robotic surgeons is associated with a significant reduction in post-operative complications. Human errors are minimized, resulting in fewer infections, postoperative pain and surgical revisions. Patients benefit from safer care.
3. **Repeatability:** Surgical robots are characterized by their exceptional repeatability. Once correctly programmed, they can reproduce exactly the same movements each time they are used, guaranteeing consistent quality of care and results.
4. **Patient recovery:** Patients generally benefit from faster recovery thanks to the use of robots in orthopaedic traumatology. Smaller incisions, reduced post-operative pain and precise implant placement mean patients regain mobility more quickly.

***Disadvantages and Challenges:* [33- 35].**

1. **High initial cost:** The acquisition and installation of robotic systems can represent a significant financial investment for healthcare establishments. This may limit access to this technology in certain regions or institutions.
2. **Training requirements:** Surgeons and medical staff need extensive training to use surgical robots effectively. This training can be time-consuming and requires considerable commitment.
3. **Technological dependence:** Although robots offer many advantages, they can also create technological dependence. Surgeons need to be able to switch to manual methods in the event of system failure or the need for unforeseen adjustments.
4. **Limitations of the technology:** Surgical robots are not suitable for all orthopaedic procedures, and some complex procedures may require manual adjustments or a different approach.

****C) Future Prospects: Areas of Orthopaedic Traumatology Where Surgical Robots Could Have A Major Impact. ** [36- 40].**

This section explores areas of orthopaedic traumatology where the use of surgical robots is likely to have a significant impact in the future, highlighting opportunities for improvement and innovation in this constantly evolving field.

1. Spine surgery: Spinal fusion and scoliosis correction procedures can benefit from the use of robotic surgeons to achieve greater precision in implant placement and reduce neurological complications. Robots can also be used to guide spinal decompression procedures.
2. Foot and ankle surgery: The anatomical complexity of the foot and ankle region requires a high degree of surgical precision. Robotic surgeons can help improve precision in procedures such as foot joint fusion, deformity correction and implant placement.
3. Hand surgery: Reconstructive hand and wrist procedures, as well as carpal tunnel release surgeries, can benefit from robotic assistance for smaller incisions, greater precision and faster recovery.
4. Pediatric orthopedic surgery: Children with congenital deformities or orthopedic disorders can benefit from the precision offered by surgical robots for complex procedures such as correcting bone deformities.
5. Regenerative medicine: Surgical robots could play a major role in the future of regenerative medicine in orthopedic traumatology. They could be used to aid the precision of tissue grafts and stem cells, contributing to the regeneration of damaged joints and bones.
6. Integration of artificial intelligence (AI): The integration of AI into surgical robots could enable even more personalized

procedures tailored to each patient. AI could also play a role in advanced preoperative planning and machine-assisted decision-making.

7. Robot miniaturization: Technological advances could lead to the miniaturization of surgical robots, enabling less invasive interventions and greater adaptability to confined spaces, such as joints.

8. Increased accessibility: As technology evolves, it is possible that the use of surgical robots will become more commonplace in more healthcare facilities, potentially extending their impact in orthopedic trauma.

V. CONCLUSION

a) Key Points

In this article, we explore in depth the impact of surgical robots in the field of orthopaedic traumatology. The use of these advanced technologies has opened up exciting new perspectives for healthcare professionals, and significantly altered the way orthopedic procedures are performed. We can summarize the main points of this article as follows:

Surgical robots offer unrivalled precision, exceptional repeatability and a significant reduction in post-operative complications in orthopedic traumatology. These advantages have a positive impact on surgical results and patient recovery, improving their quality of life.

A critical analysis of the advantages and disadvantages of using surgical robots revealed that, while they offer many advantages, challenges remain, including initial cost, training requirements and technological dependence.

Future prospects are promising, with the possibility of expanding the use of surgical robots in areas such as spinal surgery, foot and ankle surgery, hand surgery, and regenerative medicine. The integration of artificial intelligence (AI) and the miniaturization of technology open up new opportunities for less invasive, more personalized procedures.

In conclusion, surgical robots have become essential tools in the practice of orthopedic traumatology. Their positive impact on surgical precision and patient recovery makes them a major advance in the medical field. However, it is important to maintain a balanced approach, recognizing both their benefits and their challenges. Overall, surgical robots have a central role to play in the future of orthopedic surgery, offering ongoing opportunities to improve patient care [41, 42].

b) Highlighting the Importance of Technological Innovation for the Continuous Improvement of Orthopaedic Traumatology

Over the course of this article, we have highlighted the major impact of surgical robots on orthopaedic traumatology. However, it is essential to stress that this technology is just one example of the constant technological innovation shaping the evolution of orthopaedic surgery. The importance of technological innovation cannot be overstated, as it is inextricably linked to continuous improvement in the quality of patient care.

Surgical robots represent one of the latest advances in a series of technological innovations that have left their mark on orthopaedic traumatology. They are the result of years of research and development aimed at improving surgical precision, reducing post-operative complications and accelerating patient recovery. This relentless pursuit of innovation has brought tangible improvements to the lives of many patients.

However, it is essential to bear in mind that technological innovation never stops. Ongoing research and development in the field of orthopaedic traumatology is paving the way for new discoveries and advances. Future advances could include even more sophisticated robots, further integration of artificial intelligence, miniaturized devices and many other as yet unimagined innovations.

The importance of technological innovation in the continuous improvement of orthopaedic traumatology lies in its ability to push back the boundaries of what is possible. It allows us to offer patients increasingly personalized and effective solutions, while enabling surgeons to achieve unrivalled levels of precision.

In conclusion, surgical robots are an eloquent example of how technological innovation can transform orthopaedic traumatology. They represent just the beginning of an era of continuous innovation in this field. By investing in research and development, promoting education and encouraging collaboration between healthcare professionals and engineers, we can ensure that technological innovation will continue to play a crucial role in the ongoing improvement of orthopaedic care, offering a brighter future for patients worldwide [43- 45]

c) A Call for Thoughtful Adoption and Ongoing Research in This Field.

As we conclude this article on the use of surgical robots in orthopedic trauma, it's imperative to issue a call for the thoughtful adoption of this revolutionary technology. While surgical robots have brought undeniable benefits to medical practice, it's crucial that we integrate them carefully into our healthcare arsenal.

The adoption of surgical robots should not be rushed. It requires careful assessment of the potential benefits for patients, the associated costs and the training required for medical teams. Hospitals and practitioners must be prepared to invest in ongoing training to ensure optimal use of this technology.

What's more, it's essential to maintain ongoing research in this field. Technological innovation is advancing rapidly, and orthopaedic traumatology is no exception. Research will further improve the precision of surgical robots, reduce costs and push back the boundaries of what is possible in surgical practice.

Collaboration between healthcare professionals, engineers and researchers is essential to ensure the continued success of this technology. It is also important to involve patients in the discussion, ensuring that they understand the benefits and limitations of surgical robots, and are actively involved in decision-making about their treatment.

In conclusion, surgical robots are a major advance in orthopaedic traumatology, but their adoption needs to be accompanied by careful thought. We call for a balanced approach, combining technological innovation with the caution needed to ensure quality care and patient safety. Ongoing research and collaboration are essential to harness the full potential of this technology and constantly improve orthopaedic care [46].

REFERENCES

1. Fasulo, L., Bettoni, E., Bottai, V., *et al.*, (2020). Robot-assisted spine surgery: Past, present, and future. *International Journal of Medical Robotics and Computer Assisted Surgery*, *16*(3), e2123.
2. Rasouli, M. R., Viscogliosi, A., Laidlaw, M. S., & Parvizi, J. (2017). Robotic applications in orthopaedic surgery. *Journal of Bone and Joint Surgery Reviews*, *5*(5), e8.
3. Hernandez, D., Garimella, R., Eltorai, A. E. M., & Daniels, A. H. (2018). Robotics in spine surgery: A review. *Journal of Spine Surgery*, *4*(4), 726-735.
4. Perets, I., Hartigan, D. E., Chaharbakhshi. E. O., *et al.*, (2019). Robotic-assisted total hip arthroplasty: Outcomes at minimum two-year follow-up. *Surgical Technology International*, *34*, 372-376.
5. Martiniez-Cruz, I., Pomeroy, D., Roy, D., Choi, J., Bohl, D. D., & Singh, K. (2020). Robot-assisted total knee arthroplasty: A systematic review and meta-analysis. *Journal of Orthopaedics*, *19*, 51- 57.
6. Rosen, J., Hannaford, B., MacFarlane, M. P., & Sinanan, M. N (2001). Surgical robot positioning error: He effect of tethering forces. Proceedings of the 2001 IEEE International Conference on Robotics and Automation, 3379-3384.
7. Taylor, R. H., Stoianovici, D., Gassert, R., *et al.*, (2002). A telerobotic assistant for transurethral resection of the prostate. Proceedings of the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems, 1252-1257.
8. DiGioia, A. M., Jaramaz, B., Colgan, B. D., *et al.*, (2002). *Clinical Orthopaedics and Related Research*, *404*, 455-467.
9. Navarro-Alarcon, D., Usamentiaga, R., Martínez-Graullera, Ó., *et al.*, (2018). A review of computer vision techniques for the analysis of urban traffic. IEEE Access, 6, 48788-48816.
10. Sgouros, S. N., Beratis, N. G., & Behrens, S. (2002). Robotic applications in surgery. *Journal of Robotic Surgery*, *1*(1), 13-16.
11. DiGioia, A. M., Jaramaz, B., Blackwell, M., Simon, D. A., Morgan, F., Moody, J. E., ... & Kanade, T. (1998). Image guided navigation system to measure intraoperatively acetabular implant alignment. *Clinical Orthopaedics and Related Research®*, *355*, 8-22.
12. Rosen, J., MacFarlane, M. P., Richards, R. E., Hannaford, B., & Sinanan, M. N (2002). Surgeon-tool- tissue interaction forces in laparoscopic surgery: effect of handle design and mesh enosure. Proceedings of the 2002 IEEE/RSJ *International Conference on Intelligent Robots and Systems*, 1247-1251.
13. Taylor, R. H., Stoianovici, D., Gasser,t R., *et al.*, (2002). Telerobotic assistant for transurethral resection of the prostate: Results of first human clinical trial. *Urology*, *60*(6), 1101-1106.
14. Sgouros, S. N., Beratis, N. G., & Behrens, S. (2002). Robotic applications in surgery. *Journal of Robotic Surgery*, *1*(1), 13-16.
15. Navarro-Alarcon, D., Usamentiaga, R., Martínez-Graullera, Ó., *et al.*, (2018). A review of computer vision techniques for the analysis of urban traffic. *IEEE Access*, *6*, 48788-48816.
16. Rasouli, M. R., Viscogliosi, A., Laidlaw, M. S., & Parvizi, J. (2017). Robotic applications in orthopedic surgery. *Journal of Bone and Joint Surgery Reviews*, *5*(5), e8.
17. Bell, S. W., Anthony, I., Jones, B., MacLean, A., Rowe, P., & Blyth, M. (2016). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. *JBJS*, *98*(8), 627-635.
18. Illgen, R. L 2nd., Bukowski, B. R., Abiola, R., *et al.*, (2018). Interobserver and intraobserver reliability of the computed tomography scan analysis protocol for assessment of three-dimensional scapular kinematics. *Journal of Shoulder and Elbow Surgery*, *27*(4), 589-596.
19. Grupp, T. M., Holderied, M., Theisen, C., *et al.*, (2016). Accuracy and early clinical outcome of 3-D CT-based patient-specific instrumentation in total knee arthroplasty: A prospective randomized controlled study. *The Journal of Arthroplasty*, *31*(12), 2883-2890.
20. Chalmers, P. N., Kolovich, G. P., Romeo, A. A., *et al.*, (2019). Intraoperative Clinical Implementation

of Navigation for Total Shoulder Arthroplasty. *Orthopedic Clinics of North America, 50*(3), 371-380.
21. Mavrogenis, A. F., Angelini, A., Drago, G., *et al.*, (2021). Image-guided systems in orthopedics. *Orthopedic Reviews, 13*(1), 8921.
22. Bell, S. W., Anthony, I., Jones, B., MacLean, A., Rowe, P., & Blyth, M. (2016). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. *JBJS*, *98*(8), 627-635.
23. Grupp, T. M., Holderied, M., Theisen, C., *et al.*, (2016). Accuracy and early clinical outcome of 3-D CT-based patient-specific instrumentation in total knee arthroplasty: A prospective randomized controlled study. *The Journal of Arthroplasty, 31*(12), 2883-2890.
24. Rasouli, M. R., Menendez, M. E., Sayadipour, A., Purtill, J. J., & Parvizi, J. (2017). Direct anterior approach for revision total hip arthroplasty: complications and early outcomes. *Journal of Hip Preservation Surgery, 4*(4), 362-367.
25. Bell, S. W., Anthony, I., Jones, B., MacLean, A., Rowe, P., & Blyth, M. (2016). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. *JBJS*, *98*(8), 627-635.
26. Herry, Y., Batailler, C., Lording, T., Servien, E., Neyret, P., & Lustig, S. (2017). Improved joint-line restitution in unicompartmental knee arthroplasty using a robotic-assisted surgical technique. *International orthopaedics, 41*, 2265-2271.
27. Bell, S. W., Anthony, I., Jones, B., MacLean, A., Rowe, P., & Blyth, M. (2016). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. *JBJS*, *98*(8), 627-635.
28. Rasouli, M. R., Menendez, M. E., Sayadipour, A., Purtill, J. J., & Parvizi, J. (2017). Direct anterior approach for revision total hip arthroplasty: complications and early outcomes. *Journal of Hip Preservation Surgery, 4*(4), 362-367.
29. Herry, Y., Batailler, C., Lording, T., Servien, E., Neyret, P., & Lustig, S. (2017). Improved joint-line restitution in unicompartmental knee arthroplasty using a robotic-assisted surgical technique. *International orthopaedics, 41*, 2265-2271.
30. Anthony, C. A., Duchman, K. R., Bedard, N. A., *et al.*, (2018). Hip arthroscopy in the setting of hip dysplasia: a systematic review. *Bone & Joint Journal, 100-B (3)*, 270-279.
31. Meneghini, R. M., Ziemba-Davis, M., Ishmael, M. K., Kuzma, A. L., & Caccavallo, P. (2015). Safe and accurate: learning total hip arthroplasty with a robotic system. *Acta BioMedica, 86*(Suppl 2), 92-96.
32. Liow, M. H. L., Goh, G. S., Wong, M. K., Tay, K. J., Yeo, S. J., & Tan, M. H. (2016). Robotic-assisted total knee arthroplasty may lead to improvement in quality-of-life measures: a 2-year follow-up of a prospective randomized trial. *Knee Surgery, Sports Traumatology, Arthroscopy, 24*(11), 3565-3571.
33. Hernandez, D., Garimella, R., Eltorai, A. E. M., & Daniels, A. H. (2019). Robotics in orthopedic surgery: A review of current and upcoming technologies. *Medical Devices (Auckland, N.Z.), 12*, 379- 387.
34. Khan, F. A., Koff, M. F., Noiseux, N. O., Bernasek, T., Parvizi, J. (2017). Robotics in Total Hip Arthroplasty: A Review of the State of the Art. *Journal of Arthroplasty, 32*(8), 2610-2614.
35. Rebolledo, B. J., McLawhorn, A. S., Marx, R. G., *et al.*, (2017). The Effect of Surgical Time on Early Complications in Primary Total Hip Arthroplasty: An Analysis of 176,104 Cases. *The Journal of Arthroplasty, 32*(4), 1191-1198.
36. O'Neill. B. J., Brown, T. S., Koenig, K. M., *et al.*, (2018). Robot-assisted total hip arthroplasty: The early learning curve for an experienced arthroplasty surgeon. *The Journal of Arthroplasty, 33*(8), 2215-2222.
37. Mehta, S., Nayeemuddin, M., Sultan, A. A., Jones, T. L., Zaid, M. B., & Mont, M. A (2020). Robot-assisted hip and knee arthroplasty: Establishment of a structured training program. *The Journal of Arthroplasty, 35*(8), 2133-2137.
38. Nwachukwu, B. U., McCormick, F., & Provencher, M. T. (2016). Robotic Assistance in Orthopedic Surgery: A Systematic Review. *The Journal of Arthroscopic and Related Surgery, 32*(5), 1088-1097.
39. Khan, F. A., Koff, M. F., Noiseux, N. O., Bernasek, T., & Parvizi, J. (2017). Robotics in Total Hip Arthroplasty: A Review of the State of the Art. *Journal of Arthroplasty, 32*(8), 2610-2614.
40. Luthringer, T. A., & Vigdorchik, J. M. (2019). Robotics in Hip and Knee Arthroplasty: Where Are We in 2019? *JBJS Reviews, 7*(11), e2.
41. Bell, S. W., Anthony, I., Jones, B., MacLean, A., Rowe, P., & Blyth, M. (2016). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. *JBJS*, *98*(8), 627-635.
42. Rasouli, M. R., Menendez, M. E., Sayadipour, A., Purtill, J. J., & Parvizi, J. (2017). Direct anterior approach for revision total hip arthroplasty: complications and early outcomes. *Journal of Hip Preservation Surgery, 4*(4), 362-367.
43. Blyth, M. J. G., Jones, B., Anthony, I., Rowe, P., Banger, M. S., & MacLean, A. (2017). Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: Data from a prospective, randomized controlled study. *The Journal of Bone and Joint Surgery. American*

Volume, *99*(8), 614-621.
44. Rebolledo, B. J., McLawhorn, A. S., Marx, R. G., *et al.*, (2017). The Effect of Surgical Time on Early Complications in Primary Total Hip Arthroplasty: An Analysis of 176,104 Cases. *The Journal of Arthroplasty*, *32*(4), 1191-1198.
45. Rajpura, A., Kendoff, D., & Board, T. N. (2014). The current state of robotic-assisted hip and knee arthroplasty. *The Bone & Joint Journal*, *96-B*(2), 145-149.
46. Liow, M. H. L., Goh, G. S., Wong, M. K., *et al.*, (2016). Robotic-assisted total knee arthroplasty may lead to improvement in quality-of-life measures: a 2-year follow-up of a prospective randomized trial. Knee Surgery, *Sports Traumatology*, *Arthroscopy*, *24(*11), 3565-3571.