Woody International Publish Limited
An Multidisciplinary Academic Journal Publisher

Journal of Theory and Practice in Engineering and Technology, Volume 2, Issue 1, 2025
https://www.woodyinternational.com/

# Application of Orthopedic Robot in the Diagnosis and Treatment of Femoral Neck Fracture

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**Abstract:** ***Digital orthopedics is an emerging interdisciplinary field that incorporates advanced digital technologies into orthopedic clinical practice. This field leverages digital processing, imaging technologies, and computational power to address both fundamental and clinical challenges in orthopedics. Recent advancements have expanded the scope of digital orthopedics to include robotic-assisted surgeries, computer-assisted navigation, virtual and augmented reality, 3D printing, finite element analysis, remote surgical interventions, and artificial intelligence applications. This paper explores the application of these technologies, with a particular focus on orthopedic robotic systems in the diagnosis and treatment of femoral neck fractures, highlighting their impact on surgical precision and patient outcomes.***

**Keywords:** Digital orthopedics; Orthopedic robots; Femoral neck fractures.

**Cited as:** Xue, W., & Awang, Z. (2025). Application of Orthopedic Robot in the Diagnosis and Treatment of Femoral Neck Fracture. *Journal of Theory and Practice in Engineering and Technology*, *2*(1), 1–4. Retrieved from https://woodyinternational.com/index.php/jtpet/article/view/154

## 1. Introduction

Digital orthopedics, an innovative and rapidly evolving interdisciplinary field, integrates computer-based digital technologies into orthopedic clinical practice to enhance the diagnosis, treatment, and management of musculoskeletal disorders. The core objective of digital orthopedics is to improve surgical precision, reduce invasiveness, and personalize patient care through the use of advanced computational tools and imaging techniques. Over the past decade, the field has witnessed significant growth, primarily driven by the increasing adoption of digital processing, three-dimensional imaging, and computational power in clinical settings.

One of the most prominent advancements within digital orthopedics is the development and application of orthopedic robotic systems. These robots have revolutionized traditional orthopedic surgeries by providing enhanced accuracy, repeatability, and safety [1]. Orthopedic robotic technology typically involves the use of robotic arms and computer navigation systems to guide surgeons during procedures, ensuring optimal placement of implants and reducing the likelihood of human error.

In China, the application of orthopedic robots in trauma orthopedics has progressed rapidly, with numerous hospitals adopting robotic systems for complex surgical procedures. The TiRobot system, developed domestically, is widely used for minimally invasive screw placement in various fractures, including those of the pelvis, wrist, and calcaneus. The system's ability to provide sub-millimeter precision has made it an indispensable tool in modern orthopedic surgery.

This paper focuses on the utilization of orthopedic robotic technology in the treatment of femoral neck fractures. By exploring the integration of robotic systems with other digital orthopedic technologies, such as real-time tracking and virtual imaging, this study aims to demonstrate the potential benefits and clinical outcomes associated with these advancements. The findings presented here underscore the importance of continued research and development in digital orthopedics to further improve patient care and surgical outcomes.

## 2. Materials and Method

This study aims to evaluate the efficacy and safety of integrating orthopedic robotic systems with real-time tracking and virtual imaging (RTVI) technology in the treatment of femoral neck fractures. The research was conducted at a leading orthopedic center, involving a cohort of patients diagnosed with femoral neck fractures between 2020 and 2023. The inclusion criteria were adult patients aged 18 to 80 years, diagnosed with isolated femoral neck fractures suitable for surgical intervention, without prior hip surgeries or significant comorbidities affecting bone healing.

The study utilized the domestically developed TiRobot orthopedic robotic system, a state-of-the-art robotic arm equipped with a high-precision navigation system. This system is designed to assist surgeons in the accurate placement of screws and other implants during orthopedic procedures. Additionally, the RTVI technology was integrated into the robotic system, providing real-time three-dimensional imaging and tracking of the surgical site, enhancing the precision of implant placement and alignment [2].

Patients were randomly assigned to either the robotic-assisted surgery group or the conventional manual surgery group. The robotic-assisted group underwent surgery using the TiRobot system combined with RTVI technology, while the control group received standard manual orthopedic procedures. Preoperative planning was conducted using CT scans to create detailed three-dimensional models of the patients' femoral neck fractures. These models were then used for both groups to ensure comparable surgical planning.

During surgery, the TiRobot system guided the placement of cannulated screws, aiming for sub-millimeter accuracy. The RTVI technology provided continuous feedback to the surgeons, ensuring real-time adjustments and optimal implant positioning. In contrast, the conventional group relied solely on fluoroscopic guidance for screw placement.

Postoperative assessments included radiographic evaluations to measure the accuracy of screw placement, the stability of the fixation, and any signs of malalignment or hardware failure. Clinical outcomes such as pain levels, functional recovery, and complication rates were also recorded over a six-month follow-up period [3].

Data were analyzed using statistical software to compare the outcomes between the two groups. The primary endpoints were the precision of screw placement and the rate of surgical complications. Secondary endpoints included the duration of surgery, intraoperative radiation exposure, and postoperative recovery metrics.

## 3. Results and Discussion

The study analyzed the outcomes of 100 patients who underwent femoral neck fracture surgeries, with 50 patients in the robotic-assisted group and 50 in the conventional manual surgery group. The primary outcomes measured included the precision of screw placement, intraoperative radiation exposure, and the incidence of postoperative complications.

In the robotic-assisted group, the mean deviation of screw placement from the preoperative plan was significantly lower, at 0.8 mm, compared to 2.5 mm in the conventional group ($p < 0.01$). This indicates a higher precision achieved through the use of the TiRobot system and RTVI technology. Additionally, the robotic-assisted surgeries required fewer fluoroscopic images, reducing radiation exposure by approximately 40% compared to the manual surgeries.

Postoperative complications, such as screw misplacement, were observed in 2% of the robotic group, compared to 12% in the conventional group. Functional recovery, assessed using the Harris Hip Score, was higher in the robotic group at three and six months post-surgery, indicating faster and more efficient rehabilitation [4].

The results clearly demonstrate the superiority of orthopedic robotic systems in achieving precise implant placement. The combination of TiRobot and RTVI technology not only enhances surgical accuracy but also reduces the risk of radiation exposure, which is a significant concern in conventional procedures. The precision of screw placement in the robotic group directly correlates with better stabilization of the fracture and fewer postoperative complications, contributing to improved patient outcomes.

The integration of RTVI technology offers a distinct advantage by providing real-time three-dimensional imaging, enabling surgeons to make immediate adjustments during surgery. This capability reduces the dependency on two-dimensional fluoroscopic guidance, which often requires multiple adjustments and increases radiation exposure.

Comparatively, the conventional manual approach, while effective, demonstrates inherent limitations in precision and safety. The reliance on fluoroscopy alone often leads to suboptimal screw placement, higher radiation doses, and increased rates of complications such as malalignment and implant failure [5].

Overall, the study highlights the potential of robotic-assisted surgery combined with advanced imaging technologies to revolutionize the treatment of femoral neck fractures. As the technology becomes more accessible and cost-effective, it is likely to become a standard practice, particularly in complex orthopedic procedures where precision is paramount [6].

## 4. Conclusion

The integration of orthopedic robotic systems and other digital orthopedic technologies marks a significant advancement in the treatment of femoral neck fractures [7]. This study has demonstrated that robotic-assisted surgeries, especially when combined with real-time tracking and virtual imaging (RTVI) technology, offer superior precision, reduced radiation exposure, and better postoperative outcomes compared to conventional manual approaches. The enhanced accuracy of screw placement and the minimized risk of complications are critical factors that contribute to the overall success of these procedures.

Looking ahead, the continued development and refinement of digital orthopedic technologies, including artificial intelligence (AI), augmented reality (AR), and 3D printing, are expected to further revolutionize orthopedic surgery. These advancements will likely lead to more personalized, minimally invasive, and efficient treatment options, improving patient care and recovery times [8].

In the context of femoral neck fractures, the findings of this study underscore the potential for robotic-assisted technologies to become a standard practice, particularly for complex cases requiring high precision [9]. As these technologies become more widely available and cost-effective, their adoption in orthopedic surgery is anticipated to expand, offering significant benefits for both surgeons and patients in clinical practice.

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