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ORIGINAL RESEARCH ARTICLE

Impact of Tianji orthopedic robot on patient satisfaction and quality of life

Jamal Alshorman[1]* and Ruba Altahla[2]*

[1]Department of Orthopedics, Second Affiliated Hospital of Hainan Medical University, Haikou, Hainan, China

[2]Department of Rehabilitation, Second Affiliated Hospital of Hainan Medical University, Haikou, Hainan, China

Abstract

Internal fixation (IF) surgery has been promoted with the combination of robotic technology, promising increased accuracy and improved patient prognosis. This study examined the effect of IF surgery using Tianji orthopedic robot on patient satisfaction and quality of life (QoL) over a longitudinal follow-up time. A cohort of 387 patients undergoing IF guided by Tianji orthopedic robot surgery was followed from the pre-surgery phase through 12 months post-surgery. Patient-reported outcome measures, including the Oswestry Disability Index (ODI) and the Short Form Health Survey (SF-36), were administered at baseline, 6 months, and 12 months. In addition, the Newcastle Satisfaction with Nursing Care Scale (NSNCS) was also used to assess patient satisfaction. Data were analyzed using repeated measures analysis of variance. However, only 338 (87.33%) patients who underwent robot-assisted surgery completed the survey. A total of 214 (63.31%) females and 124 (36.68%) males, with an age of 63.76 ± 14 years, were included in the study. The study indicated significant progress in patient satisfaction and QoL. The mean ODI score decreased from 79.1 ± 4.76 pre-surgery to 46.2 ± 6.09 at 12 months (p<0.001), compared to the SF-36 score from 43.5 ± 4.20 to 84 ± 4.8 (p<0.05). Moreover, the NSNCS scores of 86 ± 4.32 reflected high satisfaction levels, indicating that participants were satisfied with their surgical outcomes at the 12-month follow-up. The Tianji orthopedic robot significantly improves patient satisfaction and QoL over a year. These findings confirm the significance of robotic technology and surgical procedures and highlight the essential role of nurses in using telehealth for continuous follow-up care.

Keywords: Tianji orthopedic robot; Spinal cord abnormalities; Satisfaction; Quality of life; Nursing

***Corresponding authors:**
Jamal Alshorman
(jamalking61@yahoo.com)
Ruba Altahla
(rubamntahla91@gmail.com)

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1. Introduction

The advancements in surgical techniques have altered orthopedic surgery, particularly in spinal care. Internal fixation (IF) surgery, vital for stabilizing spine abnormalities, has traditionally involved complex procedures with different outcomes.[1] Recent achievements, such as robot-assisted surgery, have enhanced surgical accuracy and may improve patient prognosis.[2-6]

Spinal cord abnormalities cover a range of conditions that influence the structure or function of the spinal cord.[6-8] Common types of spinal cord abnormalities include spina bifida, tethered cord syndrome, and spinal cord tumors. These abnormalities can cause different symptoms, such as pain, weakness, sensory loss, and deteriorated mobility, significantly affecting the patient's quality of life (QoL).[9]

The prevalence of spinal cord abnormalities differs according to the specific condition.[10] For example, spina bifida occurs in about 1 in 1000 live births, while spinal cord injuries, which often occur after trauma, affect approximately 54 individuals per million annually. Increased awareness, advances in medical technology, and research innovations have improved early detection and management, which affect both incidence and outcomes.[11]

The Tianji orthopedic robot showed significant advancement, offering higher accuracy in screw placement and decreased intraoperative complications.[12] This robotic technology improves surgical efficiency and seeks to elevate the overall patient experience and prognosis.[12,13] As patient satisfaction and QoL are paramount considerations in health care, understanding the effect of such developed technologies is definitive.

The most significant contribution of robotics to orthopedics is its ability to increase surgical accuracy. The traditional surgical techniques mainly depend on the surgeon's skills, which increases the chance of inattentive errors. Moreover, robotic systems combined with advanced imaging and real-time feedback techniques allow surgeons to plan and perform surgery with high accuracy.[14]

The high accuracy level needed minimizes disruption of soft tissue, resulting in reduced post-surgery complications and recovery periods. Developing a multidisciplinary strategy requires structured communication and cooperation, where each healthcare providers share their insights into improving patient safety and surgical sufficiency.[15-17] Specifically, nurses play a fundamental role in perioperative care, providing essential assessments, monitoring, and support associated with the surgical procedure.[18,19]

Patient satisfaction covers various aspects, including pain management, functional recovery, and the overall experience of care, while QoL includes a patient's physical, emotional, and social well-being.[20,21] It is essential to highlight the importance of these factors in assessing how robotic-assisted IF surgery influences the patients over time.

This longitudinal follow-up study aims to investigate the effects of IF surgery using the Tianji orthopedic robot on patient satisfaction and QoL. By involving validated patient-reported outcome measures and conducting assessments at multiple follow-up times, this research seeks to show overall insights into the long-term advantages of robotic-assisted surgery. In addition, the study explores the role of nursing care and telehealth in assisting and facilitating continuous follow-up, further improving the patient experience and outcomes. Finally, through this investigation, the study aims to contribute beneficial knowledge to the field of orthopedic surgery and consolidate evidence-based practices that prioritize patient-centered care.

2. Materials and methods

2.1. Participants and data collection

The patient's data were collected from two hospitals between December 2023 and November 2024. Only experienced physicians and nurses were allowed to collect and record the data. This study included patients with spinal cord abnormalities, whether the patient underwent surgery with or without an assisted robot, with at least 12 months of follow-up time. The demographic data, imaging studies, fracture characteristics, and operation data were collected and analyzed.

Before the questionnaire, patients received a brief explanation of the research study and the purpose of using the collected data. Patients were required to answer all questions before submitting the survey at the pre-operation stage. A self-administered questionnaire was distributed using the Baidu forms platform and shared via Chinese social media platforms (WeChat and QQ) for patient follow-up. However, patients who received the online questionnaire were required to confirm their desire to participate in the survey. Participation in this study was voluntary, no compensation was provided, no identifying details were collected, and data collection was anonymous. Demographic and injury data were collected from patient records and imaging studies, following the principles outlined in the Helsinki Declaration. This study was approved by the ethics committee of The Second Affiliated Hospital of Hainan Medical University.

2.2. Inclusion/exclusion criteria

The inpatients who were ≥18 years old, capable of understanding the study, and agreed to participate were included. Patients who were unable to complete the questionnaire, with cognitive impairments, or did not provide consent, either personally or through a family member, were excluded.

2.3. Sample size

The Raosoft calculator (Raosoft Inc., United States) was utilized to set the sample size for our study, based on the

total number of patients who underwent spine surgery. We applied a response distribution of 50%, a confidence interval of 95%, a standard deviation of 1.96, and a margin of error of 5%. This calculation showed a required sample size of 213. In addition, we accounted for a 10% margin ($n = 22$) to address any errors in questionnaire completion. Ultimately, 338 participants voluntarily responded, completed the survey, and were included in the final analysis.

2.4. Instrument

2.4.1. Oswestry Disability Index (ODI)

The ODI consists of 10 sections, including pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and employment/homemaking. Participants selected statements that best describe their condition. Responses were scored from 0 to 5, with higher scores representing severe disability. The total score was then converted to a percentage, where higher percentages indicate greater disability. In the Chinese version, the Cronbach's α value is 0.81 and the validity index is 0.86.[22]

2.4.2. Short Form Health Survey (SF-36)

The SF-36 is a widely used patient-reported outcome measure that assesses health-related QoL. Moreover, it provides an overall physical and mental health status. This survey included 36 questions divided into eight sections, each scored from 0 to 100, with higher scores indicating a better health status.

The scores were then summarized to create a physical component summary and a mental component summary. In the Chinese version, the Cronbach's α value was 0.88 and the validity index was 0.94.[23]

2.4.3. Newcastle Satisfaction with Nursing Care Scale (NSNCS)

Li *et al.*[23] verified the validity and reliability of the NSNCS scale in the Chinese version. This scale is a 5-point Likert scale with 19 items; one is nursing care. The final score of the evaluation ranges from 0 to 100 points. The total score elucidates the patient's satisfaction with nursing care. The Cronbach's α value and the validity index were 0.94 and 0.93 in the Chinese version, respectively.[24] The NSNCS scale was used to assess patient satisfaction with nursing care among those who underwent spine surgery assisted with the Tianji robot.

2.5. Ethical considerations

The ethical committee of The Second Affiliated Hospital of Hainan Medical University approved the study with ethical approval number: HMU-IRB20210314. All procedures were conducted following the ethical principles outlined in the 1964 Declaration of Helsinki and its subsequent revisions. The study method abides by the relevant guidelines and regulations. Informed consent was gained from all participants and their family members. Moreover, consent was acquired from legally authorized representatives if the patient was illiterate. The researchers explained the study's purposes to the patients and their family members before collecting their data.

2.6. Data analysis

Statistical Package for the Social Sciences (29.0, IBM, United States) was used to analyze the collected data. Categorical variables were reported as frequencies and percentages, while continuous data were presented as mean ± standard deviation. One-way analysis of variance was performed to compare QoL and participant satisfaction throughout the follow-up time. Multiple linear regression analyses were performed to identify key determinants of the ODI, SF-36, and NSNCS scores. Variables were selected based on the patients' theoretical or clinical significance, as well as their statistical significance, to control for potential confounding effects. The significance level (p-value) in this study was set at 0.05.

3. Results

This study included 387 patients who underwent spine surgery assisted by the Tianji robot. However, only 338 (87.33%) patients completed the survey.

3.1. Demographic characteristics

Among 338 participants, there were 214 (63.31%) females and 124 (36.68%) males, with a 1.72:1 ratio of females versus males. The mean age of the participants was 63.76 ± 14 years. The mechanism of injury was traumatic in 260 (76.92%) and non-traumatic in 78 (23.07%) patients. Associated fractures mostly involved the lower extremities (166/338, 49.11%). The most commonly affected spine region was lumbar (190/338, 56.21%), followed by thoracic (99/338, 29.28%), thoracolumbar (33/338, 9.76%), and cervical (14/338, 4.14%) (Table 1).

The robot-assisted surgery involved in this study included robotic navigation system (76/338, 20.9%), robot-assisted closed reduction and IF (62/338, 18.34%), robot-assisted balloon (47/338, 15.7%), robot-assisted percutaneous balloon dilatation (15/338, 4.43%), 5G remote robot-assisted closed reduction (6/338, 1.77%), and robot-assisted balloon vertebroplasty (7/338, 2.07%).

3.2. Comparison of QoL and satisfaction at pre-surgery, 6-month, and 12-month follow-ups among patients who underwent Tianji robot-assisted surgery

Figure 1 shows significant changes in the ODI, SF-36, and NSNCS scores across pre-surgery and 2 follow-up times.

Table 1. Descriptive characteristics of patients who underwent spinal surgery assisted with Tianji robot

Variable	*n* (%)	Mean±SD
Gender		
Male	124 (36.68)	-
Female	214 (63.31)	-
Age (years)	-	63.76±14
Surgical type		
Robot-assisted closed reduction and internal fixation	62 (18.34)	-
Robotic navigation-assisted	70 (20.71)	-
Robot-assisted balloon	47 (15.7)	-
Robot-assisted percutaneous balloon dilatation	15 (4.43)	-
5G remote robot-assisted closed reduction	6 (1.77)	-
Robot-assisted balloon vertebroplasty	7 (2.07)	-
Associated fractures		
Upper extremity fractures	93 (27.51)	-
Lower extremity fractures	166 (49.11)	-
Others*	79 (23.37)	-
Fracture type		
Traumatic	260 (76.92)	-
Non-traumatic	78 (23.07)	-
Fracture region		
Lumbar	190 (56.21)	-
Thoracic	99 (29.28)	-
Thoracolumbar	33 (9.76)	-
Cervical	14 (4.14)	-
Admission to surgery (days)	-	3.03±1.60

Note: *Other fractures.
Abbreviation: SD: Standard deviation.

Among the 3 time points: Pre-surgery, 6-month, and 12-month post-surgery, there were significant changes in the ODI scores over different categories, including pain intensity, personal care, lifting, walking, sitting, standing, traveling, and employment/homemaking. In addition, the physical component summary subscale of the SF-36 scores showed significant differences throughout the three follow-up periods (p=0.014). In contrast, the mental component summary did not show any significant changes. The NSNCS scores showed significant changes throughout the follow-up periods (p=0.034) (Table 2).

3.3. Predictors of QoL and satisfaction using multiple regression analyses

Multiple linear regression analyses were performed to recognize the key factors affecting QoL and satisfaction scores. To control for potential confounding factors and

Table 2. Comparison of quality of life and patient satisfaction at pre-surgery and two follow-up points among those who underwent Tianji robot surgery

Scales	Pre-surgery	6-month follow-up	12-month follow-up	*p*-value
ODI				
Pain intensity	76±2.76	48±7.98	32±4.28	0.012
Personal care	87±6.98	35±5.90	22±8.54	<0.001
Lifting	83±7.46	62±3.75	58±6.73	0.045
Walking	79±3.65	58±9.65	44±3.54	0.005
Sitting	77±4.98	54±2.65	49±6.32	0.032
Standing	88±4.43	76±8.56	63±5.42	0.028
Sleeping	70±4.21	66±7.35	59±5.82	0.087
Social life	504±206.98	43±8.65	32±9.54	0.531
Traveling	93±1.76	80±4.66	58±3.94	0.018
Employment/ homemaking	88±4.43	71±6.32	45±6.82	0.021
SF-36				
PCS	34±5.87	51±3.23	79±4.78	0.014
MCS	53±2.54	75±5.87	89±4.82	0.067
NSNCS	48±7.43	65±6.09	86±4.32	0.034

Abbreviations: MCS: Mental component summary; NSNCS: Newcastle Satisfaction with Nursing Care Scale; ODI: Oswestry Disability Index; PCS: Physical component summary; SF-36: Short Form Health Survey-36.

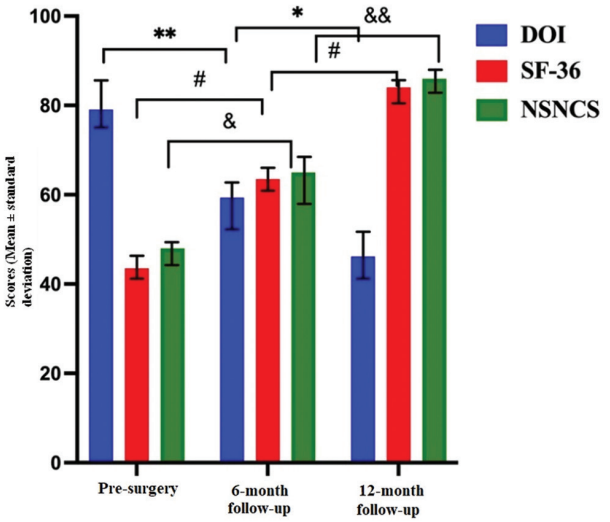

Figure 1. The ODI, SF-36, and NSNCS scores of pre-surgery and two follow-up sessions
Notes: *, #, and & indicate significant differences among ODI, SF-36, and NSNCS across different time points, with p<0.05; **, ##, and && indicate significant differences among ODI, SF-36, and NSNCS across different time points, with p<0.01.
Abbreviations: NSNCS: Newcastle Satisfaction with Nursing Care Scale; ODI: Oswestry Disability Index; SF-36: Short Form Health Survey-36.

ensure statistical significance, variables were selected according to their theoretical and clinical relevance.

The analyses revealed that several predictors, including age, surgical method, surgery type, fracture type, fracture region, and admission time, were significantly associated with the ODI, SF-36, and NSNCS scores (Table 3).

4. Discussion

Spinal cord injuries are common health issues that show significant physical, psychological, and economic challenges.[25] Spinal cord abnormalities can cause mobility issues, chronic pain, and neurological symptoms, which affect an individual's overall QoL. In addition, the psychosocial impacts include increased anxiety, depression, and social isolation, frequently aggravated by societal prejudice.[26]

The involvement of robots in IF surgery has emerged as a significant achievement in orthopedic surgery and care.[27,28] Robotic technology like the Tianji orthopedic robot ensures high surgical accuracy, which lead to high accuracy level of screw placement.[28] This accuracy reduces tissue damage, operative time, and risk of complications.[29] There was a significant reduction in the ODI scores, indicating that patients experienced less pain and high functional ability. This finding supports the advancements in surgery that lead to sensible improvements in recovery and QoL, consistent with previous studies.[30,31] In contrast, Liow *et al.*[32] reported no significant differences in the physical function throughout the follow-up periods.

The significant increase in the SF-36 scores shows a considerable improvement in patients' QoL and well-being. This improvement includes psychological and social dimensions of health. Robot-assisted surgeries may contribute to these QoL enhancements by improving recovery and reducing long-term effects, consistent with findings from previous studies.[33-35]

Table 3. Multiple regression analyses of predictors influencing quality of life and satisfaction among patients who underwent Tianji robot surgery

Characteristics	ODI		SF-36		NSNCS	
	β	*p*-value	β	*p*-value	β	*p*-value
Gender	3.31	0.103	0.85	0.667	14.67	0.393
Age	5.38	<0.001	6.58	0.027	5.38	0.039
Surgical type	0.37	0.44	1.88	0.203	1.28	0.486
Associated fractures	3.07	0.044	−0.02	0.989	2.36	0.147
Fracture type	3.92	0.038	5.98	0.017	7.69	0.011
Fracture region	5.76	0.032	7.32	0.050	7.96	0.025
Admission to surgery	4.19	<0.001	0.30	0.799	−2.07	<0.001

Abbreviations: NSNCS: Newcastle Satisfaction with Nursing Care Scale; ODI: Oswestry Disability Index; SF-36: Short Form Health Survey-36.

The high levels of satisfaction in the NSNCS scores highlight the essential role of both surgical and nursing care in the overall patient experience. The positive effect of robot-assisted surgery on patient care may arise from various factors, including reduced pain, faster recovery times, and improved post-operative assistance, which aligns with previous research findings.[36,37] Furthermore, the use of telehealth for persistent follow-up underscores the role of nurses in providing continuous care and monitoring, which can improve patient satisfaction. However, factors such as patient age, associated fractures, fracture type, fracture region, and admission to surgery time are significant predictors of lower QoL and patient satisfaction.

This study confirms the importance of multidisciplinary cooperation in patient care. Collaboration between surgeons, nursing staff, and rehabilitation staff is essential in optimizing patient prognosis. The involvement of nurses in the telehealth follow-up time allows for timely interventions, addresses any concerns that may arise during recovery, and helps create a supportive environment for patients.

As robot technology continues to develop, further research is required to assess its long-term effects across diverse patient populations and different types of orthopedic surgery. Effectively integrating robot systems into clinical practice will be substantial for maximizing their benefits. In addition, future studies should explore the cost of robot-assisted surgeries compared to traditional methods, as well as the training and support required for healthcare professionals to confirm the advantages of these technologies.

This is the first study to evaluate changes in patient satisfaction and QoL following IF surgery with the Tianji orthopedic robot, with assessments estimated by nursing staff using telehealth services. This study has some limitations. The primary limitation is the dependence on patient-reported outcome measures, such as the ODI and the SF-36. This reliance may introduce response bias, as patients might overestimate or underestimate their satisfaction and QoL. The second limitation is the lack of a control group, making it difficult to attribute improvements in the robot-assisted surgery. The third limitation is that other unmeasured factors may affect patient outcomes, complicating the interpretation of the outcomes.

5. Conclusion

The Tianji orthopedic robot-assisted IF surgery significantly enhances patient satisfaction and QoL over a 12-month follow-up period, by analyzing patient-reported outcomes including the ODI, SF-36, and NSNCS scores. Moreover,

the Tianji orthopedic robot represents a transformative tool in spinal surgery, combining technological innovation with nursing-led continuous care to enhance patient-centered outcomes. These results underscore the importance of robotic technology and multidisciplinary collaboration in modern orthopedics.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: All authors
Formal analysis: Ruba Altahla
Investigation: Jamal Alshorman
Methodology: Ruba Altahla
Writing – original draft: All authors
Writing – review & editing: All authors

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of The Second Affiliate Hospital of Hainan Medical University (protocol code HMU-IRB20210314). Informed consent was obtained from all individual participants included in the study.

Consent for publication

All participants provided informed consent for the publication of the findings derived from this study. Where applicable, participants gave explicit permission for the publication of any data, images, or information that could potentially reveal their identity. The authors affirm that all relevant consent forms have been obtained and are available upon request.

Availability of data

Data are available upon request via the corresponding author.

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