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ORIGINAL RESEARCH

The Influence of Preoperative Central Sensitization on the Postoperative Prognosis of Pilon Fractures: A Retrospective Study

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Purpose: Although surgical techniques have improved, chronic pain, functional impairment and psychological effects still occur after pilon fracture surgery. The aim of this study is to evaluate the clinical efficacy after pilon fracture surgery and to explore the impact of preoperative patients with central sensitization (Central Sensitization, CS) on the improvement of postoperative pain, function, anxiety/depression.

Patients and Methods: In this single-center retrospective study, we collected adult (≥18 years old) patients with pilon fractures who underwent open reduction and internal fixation at Xi'an Honghui Hospital from January 2020 to July 2024 and had the cognitive ability to complete the questionnaire. Exclusion criteria included incomplete medical records, concurrent other foot fractures, or severe mental disorders. The preoperative central sensitization (CS) determination criteria were a score of ≥18 on the Chinese version of the 9-item Central Sensitization Inventory (CSI-9). The assessment indicators at baseline and the last follow-up included the Visual Analogue Scale (VAS) for pain, the American Orthopaedic Foot & Ankle Society Hindfoot Score (AOFAS), and the Hospital Anxiety and Depression Scale (HADS). Patients were divided into the CS group and the non-CS group based on whether they had a preoperative central sensitization state, and the differences in baseline characteristics, pain severity, functional performance, and psychological state between the two groups were compared.

Results: At the final follow-up, the performance of the CS group was worse than that of the non-CS group, VAS was 20.04±6.87 compared to 14.15±6.34 ($P < 0.001$); AOFAS was 77.71±9.55 compared to 86.21±6.57 ($P < 0.001$); HADS-A was 6.39±2.87 compared to 3.00 (2.00, 4.00); HADS-D was 6.39±3.06 compared to 3.00 (2.00, 3.00). In terms of improvement degree, there were significant differences between the two groups in the improvement of pain and anxiety/depression ($p < 0.05$).

Conclusion: Both groups of patients showed significant improvement in pain relief, functional activity, and psychological state postoperatively compared to preoperatively. However, patients with preoperative CS showed less improvement in pain relief, functional recovery, and psychological state compared to those without CS. Therefore, foot and ankle surgeons should further investigate the impact of preoperative interventions for CS on postoperative outcomes in future studies.

Keywords: pilon fracture, central sensitization, CSI-9, open reduction and internal fixation, prognosis, psychological status

Introduction

Pilon fractures refer to fractures involving the weight-bearing surface of the distal tibial joint, and are relatively rare in clinical practice.[1] The distal tibia has anatomical features such as weak soft tissue coverage, poor blood supply, and a wide medullary cavity, which make the treatment of pilon fractures a significant challenge in orthopedic practice.[2] Currently, there are various surgical treatments for pilon fractures. Among them, Open Reduction and Internal Fixation (ORIF) is a common surgical approach that effectively restores the normal anatomical structure of the joint surface.[3–6]

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However, patient outcomes are influenced by multiple factors. Studies have found that by modulating the state of Central Sensitization (CS), effective pain management can be achieved, which in turn affects the patient's cognition, functional status, and quality of life.[7,8] Furthermore, changes in the CS state have a significant predictive effect on postoperative recovery.[9,10] A study by J. Ryan Martin et al found that in patients with coexisting psychological symptoms, CS is closely linked to poor functional outcomes.[11] Additionally, research has shown that the Central Sensitization Inventory (CSI) can serve as an effective predictor of decreased quality of life.[12,13] It is designed to identify patients with Central Sensitization Syndrome. Therefore, preoperative assessment and intervention of the CS state in pilon fracture patients is crucial for optimizing surgical outcomes and promoting overall recovery.

Although ORIF is a commonly used method for treating pilon fractures in clinical practice, there is still limited research on the impact of preoperative CS on surgical outcomes. This study aims to investigate the incidence of preoperative central sensitization in pilon fracture patients and to explore the associations between pre-operative CS scores and post-operative pain intensity, functional outcomes and psychological status (anxiety and depression). Provide reference for clinical doctors to formulate surgical plans, thereby further improving surgical efficacy and patient satisfaction.

We hypothesized that elevated patients with the CS condition before the surgery had a poorer degree of postoperative pain relief, functional recovery, and improvement in psychological state compared to those without the CS condition.

Patients and Methods

This retrospective study has been approved by the Ethics Committee of Xi'an Jiaotong University Affiliated Honghui Hospital / Xi'an Honghui Hospital, with the approval number: No.: 2025-KY-031-01, All the subjects signed the informed consent form and followed the principles of the Helsinki Declaration. This study conducted a retrospective analysis of patients diagnosed with pilon fractures and discharged from Xi'an honghui Hospital from January 2020 to July 2024. Inclusion criteria: 1) Patients who underwent surgical treatment for pilon fractures; 2) Age ≥18 years; 3) Ability to independently complete the survey based on language and cognitive skills. Exclusion criteria: 1) Incomplete clinical data; 2) Presence of other foot fractures, such as talus, calcaneus, or metatarsal fractures; 3) History of psychiatric disorders; 4) Conditions such as cancer or rheumatoid arthritis.

To ensure consistency in study variables, all surgeries were performed by the same senior foot and ankle surgeon to standardize surgical techniques and anesthesia methods. Postoperative medication and treatment protocols were also standardized for all patients.

After obtaining approval from the Ethics Committee, we accessed the patients' contact information through the medical record system and invited them to participate in this study. This study collected baseline data, including age, gender, BMI, and follow-up duration, and required participants to complete questionnaires assessing subjective experiences and functional evaluations. We used the Chinese version of the 9-item Central Sensitization Inventory (CSI-9) to assess the CS status of patients preoperatively. The CSI-9 is a simplified version of the 25-item Central Sensitization Inventory (CSI-25). CSI-9 is a patient-reported tool designed to identify individuals at risk of CS among those with chronic pain. The CSI-9 consists of two parts. Part A includes nine questions assessed using a 5-point Likert scale (0: Never; 1: Rarely; 2: Sometimes; 3: Often; 4: Always), with a total score ranging from 0 to 36. Higher scores indicate a greater likelihood of CS, and a cutoff score of ≥18 demonstrates good sensitivity and specificity for identifying CS. Part B aligns with the CSI-25 and includes 10 conditions associated with CS. It collects information on patients' past diagnoses to assist in determining the presence of CS.[14] The Hospital Anxiety and Depression Scale (HADS) was used to evaluate the levels of anxiety and depression in patients before surgery and at the final follow-up. The HADS consists of two subscales: HADS-A (Anxiety) and HADS-D (Depression). Each subscale contains seven items rated on a 4-point scale ranging from 0 to 3. A total score of 8 or higher is considered the cutoff value for the presence of anxiety or depression.[15] Additionally, we used the Visual Analogue Scale (VAS) to assess the severity of pain before surgery and at the final follow-up. The VAS consists of a 10-cm horizontal line, with one end representing no pain (0 points) and the other end representing the worst possible pain (100 points). Patients mark their perceived level of pain on the line based on their subjective experience.[16] Additionally, we used the American Orthopaedic Foot & Ankle Society Hindfoot Score (AOFAS) to evaluate functional outcomes at the final follow-up. The AOFAS scoring system provides a quantitative

assessment of patients' foot health and tracks improvements throughout the treatment process. All raters underwent appropriate training to ensure the accuracy of the scoring process. All questionnaires and clinical data were entered into an electronic database following a standardized protocol and anonymized to ensure data accuracy and patient privacy. Based on the preoperative CSI-9 scores, patients were divided into two groups: the CS group (preoperative CSI-9 ≥18) and the non-CS group (preoperative CSI-9 < 18).

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 26 (IBM Corporation, USA). First, normality tests were conducted on all continuous variables to assess whether the data followed a normal distribution. For normally distributed data, values are presented as the mean ± standard deviation (Mean ± SD), with independent samples *t*-test used for between-group comparisons and paired samples *t*-test for within-group comparisons. Non-normally distributed data are presented as median (interquartile range) [M (P25, P75)], with the Mann–Whitney *U*-test used for comparisons. Ordinal categorical variables are described using frequencies and percentages (%), with group comparisons performed using the χ^2-test.

Surgical Method

As shown in the preoperative X-ray and CT scans (see Figures 1–2). An appropriate incision was made based on the fracture pattern, and the skin, subcutaneous tissue, and fascia were sequentially incised to expose the distal tibia. The fracture ends were visualized, cleaned, reduced, and fixed using a bone plate and screws. If bone defects were present, allogeneic bone grafts were implanted. Passive movement of the ankle joint on the operating table confirmed good range of motion and stable fracture fixation. Fluoroscopy with a C-arm revealed satisfactory fracture reduction and proper placement of the internal fixation. After a thorough count of instruments and sponges, the wound was irrigated with hydrogen peroxide and normal saline. The wound was found to have high tension, and layered closure was performed to reduce tension and ensure secure closure. And X-ray and CT examinations were conducted after the operation. The postoperative imaging data are shown in Figures 3–4.

Figure 1 Preoperative X-ray imaging. (**a**) Anteroposterior view of the right ankle reveals distinct fractures of the tibia and fibula, with involvement of the distal tibial articular surface. (**b**) Lateral view of the right ankle demonstrates clear fracture lines in the tibia and fibula.

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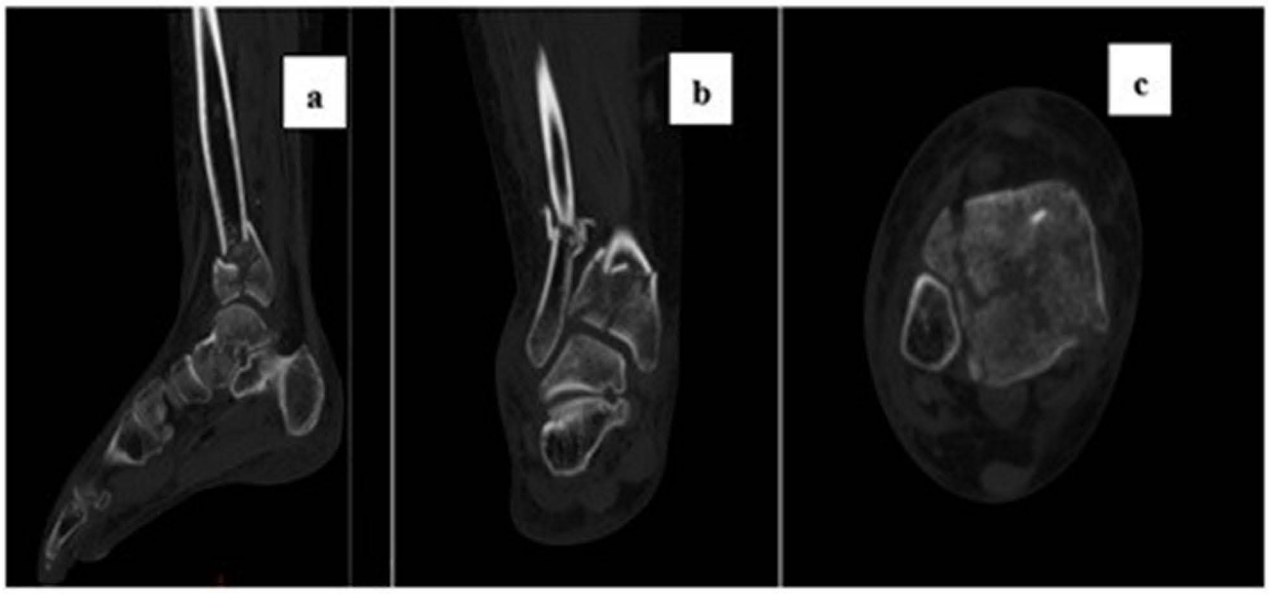

Figure 2 Preoperative Computed Tomography (CT) imaging data. (**a**) The sagittal view of the CT scan shows a fracture of the distal tibial articular surface. (**b**) The coronal view of the CT scan reveals a fracture of the distal tibial articular surface and a fracture of the fibular shaft. (**c**) The transverse section of the CT scan indicates a comminuted fracture of the distal tibial articular surface.

Figure 3 Postoperative X-ray imaging data. (**a**) Ankle acupoint; (**b**) Anteroposterior view; (**c**) Lateral view..

Result

Baseline Data

A total of 91 patients were enrolled in this study, of whom 76 completed the full follow-up. Among those who completed the follow-up, 59 were males and 17 were females. Of these, 28 patients had CS prior to surgery, including 21 males and 7 females. The median follow-up time was 27.00 months (IQR: 11.00, 38.75), and the prevalence rate was 36.84%. In contrast, 48 patients did not have CS prior to surgery, including 38 males and 10 females. The median follow-up time

Figure 4 Postoperative CT imaging data. (**a**) The coronal CT view shows internal fixation of the fibular shaft. (**b**) The coronal CT view reveals internal fixation of the distal tibia, with good reduction of the articular surface. (**c**) The sagittal CT view demonstrates internal fixation of the distal tibia, and the articular surface is well - reduced. (**d**) The transverse CT section shows the distal tibial articular surface after internal fixation and reduction.

was 18.50 months (IQR: 10.00, 39.25). Additionally, during the follow-up period, only one patient from either group developed a wound infection.

There were no statistically significant differences between the two groups in terms of gender, body mass index (BMI), or follow-up duration ($P > 0.05$). However, significant differences were observed between the two groups in terms of age, preoperative CSI-9, VAS, HADS-A, and HADS-D scores ($P < 0.05$). The detailed baseline data of the patients are presented in Table 1.

Comparison of AOFAS, VAS, HADS-A, and HADS-D Scores at the Final Follow-up Between the Two Groups

At the final follow-up, the performance of the CS group was worse than that of the non-CS group (See Table 2). The VAS score was 20.04 ± 6.87 compared to 14.15 ± 6.34 ($P < 0.001$); the AOFAS score was 77.71 ± 9.55 compared to 86.21 ± 6.57 ($P < 0.001$); the HADS-A score was 6.39 ± 2.87 compared to 3.00 (2.00, 4.00); the HADS-D score was 6.39 ± 3.06 compared to 3.00 (2.00, 3.00).

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Table 1 Baseline Data of Patients [Mean ± SD / M(Q1, Q3)]

Variables	Group CS (n=28)		Non-CS Group (n=48)		t/Z/χ^2	P
Sex (Male/Female)	21 (75%)	7 (25%)	38 (79.17%)	10 (20.83%)	0.177	0.674
Age (years)	48.21±11.43		41.54±13.74		2.168	0.033
BMI (kg/m^2)	24.76±4.21		24.66±2.66		0.124	0.902
Follow-uptime (months)	27.00 (11.00, 38.75)		18.50 (10.00, 39.25)		−0.744	0.457
Pre-CSI-9	23.29±2.14		9.50 (5.25, 14.75)		−7.245	<0.001
Pre-VAS	79.50 (68.50, 87.00)		64.54±12.89		−3.668	<0.001
Pre-HADS-A	10.18±2.41		5.00 (3.00, 6.00)		−6.458	<0.001
Pre-HADS-D	10.50 (9.00, 12.00)		5.00 (3.00, 6.00)		−6.537	<0.001

Notes: Group CS: Preoperative CSI-9 score is greater than 18; Non-CS Group: Preoperative CSI-9 score was less than 18; t: The t-value is derived from an independent samples *t*-test, which is utilized to compare the means between groups. Z: The z-value is obtained from the Wilcoxon signed-rank test, which is employed for non-parametric comparisons. χ^2: The χ^2 value is derived from the chi-square test, which is used to determine if there are significant differences between different genders. P: P values < 0.05 were considered statistically significant.
Abbreviations: BMI, Body Mass Index; Pre, preoperative; SD, Standard Deviation, Q1, First quartile; Q3, third quartile.

Table 2 Comparison of Final Follow-up Evaluation Metrics Between the Two Groups [Mean ± SD / M(Q1, Q3)]

Variables	Group CS (n=28)	Non-CS Group (n=48)	t/Z	P
VAS	20.04±6.87	14.15±6.34	3.789	<0.001
AOFAS	77.71±9.55	86.21±6.57	−4.586	<0.001
HADS-A	6.39±2.87	3.00 (2.00, 4.00)	−5.408	<0.001
HADS-D	6.39±3.06	3.00 (2.00, 3.00)	−5.698	<0.001

Notes: Group CS: Preoperative CSI-9 score is greater than 18; Non-CS Group: Preoperative CSI-9 score was less than 18 t: The t-value is derived from an independent samples *t*-test, which is utilized to compare the means between groups. Z: The z-value is obtained from the Wilcoxon signed-rank test, which is employed for non-parametric comparisons. P: P values < 0.05 were considered statistically significant.
Abbreviations: SD, Standard Deviation; Q1, First quartile; Q3, third quartile.

Analysis of Differences in Evaluation Indicators Between Preoperative and Final Follow-up Periods

After surgery, both groups of pilon fracture patients showed significant improvements in pain levels and psychological status compared to preoperative assessments (P < 0.001; see Table 3).

Comparison of Preoperative and Postoperative Differences in AOFAS, VAS, HADS-A, and HADS-D Scores Between the Two Groups

The statistical analysis results showed that there were significant statistical differences in the score differences of VAS, HADS-A, and HADS-D before and after surgery between the two groups of patients (Group CS vs non-CS group: VAS was 56.64 ± 15.64 compared to 50.40 ± 10.27 (6.25 (95% CI: 0.33, 12.17), P = 0.039); HADS-A was 3.79 ± 2.94 compared to 1.79 ± 2.01 (2.01 (1.99 (95% CI: 0.86, 3.13), p = 0.001); HADS-D was 4.00 ± 3.42 compared to 1.94 ± 2.13 (2.06 (95% CI: 0.78, 3.33), p = 0.002), as shown in Table 4). This result indicates that there are significant differences in pain degree, ankle function activity, and the improvement degree of anxiety and depression between the two groups of

Table 3 Comparison of Preoperative and Final Follow-up Data Between the Two Groups [Mean ± SD / M(Q1, Q3)]

Variables		Preoperative	Final Follow-up	t/z value	p value
Group CS (n=28)	VAS	79.50 (68.50, 87.00)	20.04±6.87	−4.624	<0.001
	HADS-A	10.18±2.41	6.39±2.87	6.823	<0.001
	HADS-D	10.50 (9.00, 12.00)	6.39±3.06	−4.266	<0.001
Non-CS Group (n=48)	VAS	64.54±12.89	14.15±6.34	34.010	<0.001
	HADS-A	5.00 (3.00, 6.00)	3.00 (2.00, 4.00)	−4.768	<0.001
	HADS-D	5.00 (3.00, 6.00)	3.00 (2.00, 3.00)	−4.828	<0.001

Notes: Group CS: Preoperative CSI-9 score is greater than 18; Non-CS Group: Preoperative CSI-9 score was less than 18; t: The t-value is derived from an independent samples *t*-test, which is utilized to compare the means between groups. z: The z-value is obtained from the Wilcoxon signed-rank test, which is employed for non-parametric comparisons. P: P values < 0.05 were considered statistically significant.
Abbreviations: SD: Standard Deviation; Q1: First quartile; Q3: third quartile.

Table 4 Change in Evaluation Metrics Between Preoperative and Final Follow-up in Both Groups [Mean ± SD]

Variables	VAS Difference	HADS-A Difference	HADS-D Difference
Group CS (n=28)	56.64±15.64	3.79±2.94	4.00±3.42
Non-CS Group (n=48)	50.40±10.27	1.79±2.01	1.94±2.13
t value	2.102	3.509	3.245
95% CI	6.25(0.33, 12.17)	1.99(0.86, 3.13)	2.06(0.78, 3.33)
p value	0.039	0.001	0.002

Notes: Group CS: Preoperative CSI-9 score is greater than 18; Non-CS Group: Preoperative CSI-9 score was less than 18; t: The t-value is derived from an independent samples *t*-test, which is utilized to compare the means between groups. P: P values < 0.05 were considered statistically significant.
Abbreviations: SD, Standard Deviation; CI, Confidence interval.

patients. Therefore, patients in the CS group before surgery had better improvement in pain, anxiety, and depression after surgery compared to those in the non-CS group before surgery.

Discussion

Pilon fractures are intra-articular fractures resulting from high-energy trauma, accounting for approximately 1% of lower limb fractures and 3–10% of tibial fractures.[17] Surgical treatment for these fractures is often ineffective, with a high incidence of complications.[18,19] Even for experienced foot and ankle surgeons, the clinical management of this type of fracture remains challenging. Existing research predominantly focuses on the impact of surgical approaches (anterior medial/lateral approaches), joint reduction techniques, and internal fixation devices on prognosis.[20–25] However, CS may also influence patient outcomes. Studies have shown that CS amplifies neural signals within the central nervous system, significantly affecting patient prognosis.[26] In this state, the brain and spinal cord respond more intensely to unpleasant stimuli, akin to "turning up the volume", thereby exaggerating pain signals.[27,28] Fracture pain typically originates from the mechanical distortion of somatosensory nerve endings that innervate the bones and muscles, and this pain may be persist through CS mechanisms.[29] Therefore, the optimal treatment strategy for acute pain is to eliminate the mechanisms of CS.[30] However, there is limited research on whether preoperative CS affects postoperative pain, function, and

psychological outcomes. Research indicates a correlation between pain perception and anxiety/depression in patients with CS.[31,32] Additionally, studies have found a correlation between preoperative CS and postoperative functional activity.[11]

The results of this study show that both groups of patients experienced significant improvements in postoperative pain and anxiety/depression compared to preoperative levels. Nayan Shrivastava et al found that ORIF significantly improves pain and functional activity in patients with pilon fractures,[33] consistent with our study's results. Additionally, T. Schlereth suggested a correlation between pain and anxiety/depression.[34] We believe that the reduction in postoperative pain in pilon fracture patients may lead to improvements in both anxiety and depression. Furthermore, during the follow-up period, only one patient experienced wound non-healing with infection. The likely causes were the lack of postoperative anti-inflammatory treatment, improper wound dressing, and the patient's residence in a remote rural area with limited medical facilities. These factors ultimately led to wound non-healing and subsequent infection. Therefore, we believe that ORIF is a safe and effective surgical approach, suitable for most pilon fracture patients.

Additionally, the results of this study show that patients in the CS group were significantly older than those in the non-CS group. Research has shown a correlation between CS and age.[35] As individuals age, the aging process can promote CS through various mechanisms, including neurodegeneration, inflammation accumulation, and neurotransmitter imbalances. These physiological changes make the elderly more susceptible to chronic pain and sensory abnormalities.[36] Therefore, early intervention targeting inflammation and neural plasticity is considered a crucial step in preventing and treating CS. Furthermore, aging may slow metabolic rates, making pathological processes such as inflammation more likely to occur and persist, thereby further promoting the development of CS.[37]

This study also found that at the final follow-up, patients in the CS group had higher HADS-A, HADS-D, and VAS scores, but lower AOFAS scores compared to those in the non-CS group. These results suggest that preoperative CS may negatively affect postoperative pain, psychological state, and functional recovery. Studies have shown that patients in the CS group report higher VAS pain scores.[38,39] Additionally, research has indicated that patients with preoperative CS typically experience higher postoperative pain scores and poorer functional recovery.[12,26,40] Therefore, in clinical practice, physicians should closely monitor CS as a predictive factor and implement interventions to manage postoperative pain, functional recovery, and psychological state, thereby improving clinical outcomes.

The results of this study show that patients with preoperative CS experienced greater improvements in postoperative pain and psychological health than those without preoperative CS. Research indicates that higher CS levels are associated with pain and anxiety/depression.[26,41,42] Preoperative CS patients already had higher pain and anxiety/depression scores. Therefore, we believe that CS patients have greater potential for improvement in postoperative pain and anxiety/depression. Furthermore, the success of the surgery and the effects of analgesics likely contributed to a reduction in CS levels, which in turn further lowered postoperative VAS and HADS scores. Additionally, patients in the non-CS group had lower preoperative VAS and HADS scores, leaving less room for improvement. As a result, patients in the CS group showed greater improvement in both pain and psychological health than those in the non-CS group.

However, this study has the following limitations: ①A small sample size, with only 76 patients successfully followed up, and the study being single-center, which may limit the generalizability of the results and introduce potential bias.②The study did not accurately record the amount of medication administered to patients before, during, and after routine analgesic anesthesia, which could introduce bias.③This is a retrospective study, which may include potential biases and confounding factors.④The second section of the central sensitization scale had limited valid data due to memory biases in the patients. To better understand the relationship between CS and ORIF surgery in the clinical outcomes of pilon fractures, future studies should be prospective, involve larger sample sizes, multi-center approaches, and long-term follow-up in randomized controlled trials.⑤This study mainly used descriptive statistics + inter-group comparison methods to compare the differences in postoperative outcomes between the CS group and the non-CS group. Without conducting multivariate analysis to fully control for potential confounding factors, this may affect the interpretation of the results. Therefore, future research should further verify the findings of this study through multivariate

models. Despite these limitations, this study provides valuable insights into the relationship between patients' CS, psychological state, pain, and functional activity.

Conclusion

The results of this study show that postoperative pain relief, functional recovery, and psychological status were significantly better in pilon fracture patients. However, patients with preoperative CS had poorer postoperative outcomes, with significantly less improvement in pain relief, functional recovery, and psychological state compared to non-CS patients. Therefore, foot and ankle surgeons should explore the impact of preoperative interventions for CS on post-operative outcomes in future studies.

Abbreviations

CS, Central sensitization; CSI-9, The Chinese version of the 9-item Central Sensitization Inventory; CSI, The Central Sensitization Inventory; VAS, The Visual Analogue Scale; AOFAS, The American Orthopaedic Foot and Ankle Society Hindfoot Score; HADS, The Hospital Anxiety and Depression Scale; CT, Computed Tomography; ORIF, Open Reduction and Internal Fixation; SD, Standard Deviation; Q1, First quartile; Q3, third quartile; BMI, Body Mass Index.

Institutional Review Board Statement

The project has been approved by the Ethics Committee of Xi'an Jiaotong University Affiliated Honghui Hospital / Xi'an Honghui Hospital, with the approval number: No.: 2025-KY-031-01.

Informed Consent Statement

Written informed consent was obtained from the patients.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

All the authors report no relevant conflicts of interest for this article.

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