Current Science
CS 5 (3), 3242-3251 (2025)
Received 21 March 2025 | **Revised 18 April** 2025 | **Accepted 25 May**. 2025 | **Online Available 23 June** 2025
https://doi.org/ 10.52845/CS/2025-5-3-90

Current Science

Current Science

OPEN ACCESS

ISSN(O)2795-8639

Original Article

Comparison of the Efficacy of 3D Printed Guide Plate-Assisted Sacroiliac Screw Internal Fixation and Manual Screw Placement in the Treatment of Sacroiliac Joint Complex Injuries

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Abstract:

Objective: This study compares the clinical efficacy of 3D printed guide plate-assisted sacroiliac screw fixation with manual screw placement for complex sacroiliac joint injuries.

Methods: We retrospectively analyzed 35 patients with sacroiliac joint injuries treated at North China Medical Health Group Fengfeng General Hospital from July 2022 to June 2024. Patients were divided into two groups: the 3D printed guide plate group (17 cases) and the manual screw placement group (18 cases). We compared intraoperative fluoroscopy times, surgical duration, screw placement time, blood loss, postoperative complications, time to full weight-bearing, fracture healing time, and hip range of motion (ROM) one month postoperatively. Screw positions were evaluated using the Gras classification, while pelvic function was assessed with the Majeed score, fracture reduction quality with the Matta score, and clinical efficacy with the visual analogue scale (VAS).

Results: No postoperative wound infections or nerve injuries occurred. Follow-up ranged from 7 to 22 months (average 14.69±4.45 months). Significant differences were noted between groups in fluoroscopy times, surgical duration, screw placement time, blood loss, time to full weight-bearing, fracture healing time, hip ROM, VAS scores, and Majeed scores ($P < 0.05$). Matta score evaluations also showed significant differences ($P < 0.05$). No significant differences were found at the last follow-up regarding hip ROM, VAS scores, or Majeed scores ($P > 0.05$).

Conclusion: 3D printed guide plates enhance sacroiliac screw placement accuracy, reduce operative time and blood loss, and promote quicker recovery, making this technique advantageous in clinical practice.

Keywords: Sacroiliac screw; 3D printed guide plate; Sacroiliac joint injuries; Internal fixation; Injury

1. Introduction

Sacroiliac joint complex injuries are prevalent orthopedic issues that compromise the stability and functionality of the joint. Clinical studies reveal that these injuries account for approximately 10% to 30% of lower back pain cases, significantly affecting patients' quality of life and imposing a considerable economic burden on the healthcare system [1]. The sacroiliac joint complex comprises a bone-ligament structure located at the back of the pelvic ring, including the ilium, sacrum, sacroiliac joint, surrounding ligaments, pelvic floor muscles, and fascia. This complex plays a crucial role in load transmission to the lower limbs, contributing to 60% of the overall pelvic function [2]. Treatment options for sacroiliac joint injuries currently encompass both conservative and surgical methods. However, traditional surgical techniques often face challenges, such as inaccurate screw placement, increased intraoperative blood loss, and extended recovery times [3]. As society progresses and

economies advance, minimally invasive treatments have emerged as the preferred and most effective solution for addressing sacroiliac joint complex injuries [4,5]. Recently, the integration of 3D printing technology into the medical field has garnered significant attention. Research indicates that 3D printed guides can markedly enhance surgical accuracy and reduce the need for intraoperative fluoroscopy sessions, ultimately improving surgical outcomes and safety [6]. This study aims to compare the efficacy of 3D printed guide technology with traditional manual screw placement techniques in the minimally invasive treatment of sacroiliac joint complex injuries.

1 Clinical Data

1.1 Inclusion and Exclusion Criteria

1.1.1 Inclusion Criteria: ①Fresh, closed pelvic fractures; ②Patients must agree to participate and sign the informed consent; ③No absolute contraindications to surgery; ④Tile types B and C pelvic fractures [7]; ⑤Significant improvement in fracture displacement following traction; ⑥Utilization of sacroiliac joint screws for fixation.

1.1.2 Exclusion Criteria: ①Old, open pelvic fractures; ②Severe injury of lumbosacral nerve requires immediate surgical exploration and repair; ③Fixation using external fixators or other non-screw methods; ④Severe osteoporosis; ⑤Inability to tolerate general anesthesia; ⑥Inability to receive minimally invasive treatment.

1.2 General Information

This study retrospectively collected data from 35 patients with sacroiliac joint complex injuries who visited the Orthopedic Department of North China Medical Health Group Fengfeng General Hospital between January 2022 and June 2024. The patients were divided into two groups based on surgical methods: a 3D printed guide plate group and a manual group.In the guide plate group, there were 11 males and 6 females, with ages ranging from 29 to 65 years and an average age of (47.29±10.63) years. The Tile classification included 6 cases of type B and 11 cases of type C. In the guide plate group, 8 cases were injured on the left side and 9 cases on the right side. Causes of injury were identified as 6 cases due to falls, 8 due to traffic accidents, and 3 from other causes. The median body mass index (BMI) was 25.91, with an interquartile range of 21.93 to 27.82 . The duration from injury to surgery in the guide plate group ranged from 6 to 9 days, while the median time from injury to operation was 7.00 days, ranging from 6.00 to 8.00 days. A total of 19 sacroiliac screws were implanted. Among the 17 cases in the guide plate group, 11 also had other injuries. In the manual group, there were 12 males and 6 females; ages ranged from 34 to 62 years, with an average of (50.28±8.59) years; Tile classification included 5 cases of type B and 13 cases of type C; In the manual group, 8 cases were injured on the left side and 10 cases on the right side. 6 cases were due to falls, 9 due to traffic accidents, and 3 from other causes. The median body mass index (BMI) was 27.47, with an interquartile range of 24.34 to 27.82. In the manual group, the time from injury to operation

ranged from 6 to 9 days, while the median time from injury to operation was 7.50 days, ranging from 6.75 to 8.00 days. A total of 20 sacroiliac screws were implanted. In the manual group, 9 out of 18 cases were associated with other injuries. No statistically significant differences were found between the two groups in terms of age, gender, height, weight, fracture classification, associated injuries, injury mechanism, time from injury to surgery, or the injured side ($P > 0.05$) (see Table 1).

Tabel 1

	cases	Sexuality (males/females)	Age(years)	BMI	Injured Side(left/right)	Fracture Classification （B/C）	Time from injury to operation (days)	Associated Injuriesno/yes）	Injury Mechanism falling/traffic accident/ others）
guide plate group	17	11/6	47.29±10.63	25.91 （21.93,27.82）	6/11	6/11	7.00 （6.00,8.00）	6/11	6/8/3
manual group	18	13/5	50.28±8.59	27.47 （24.34,27.82）	8/10	5/13	7.50 （6.75,8.00）	9/9	6/9/3
t/Z			-0.916	-1.221			-0.789		
P		0.725	0.265	0.222	0.733	0.725	0.430	0.500	0.999

In the guide plate group, The operation time varied between 76 and 99 minutes, with a median of 81.00 minutes (80.00, 85.00). The placement time for a single sacroiliac screw ranged from 23 to 33 minutes, with a median of 30 minutes (29, 31.5). Blood loss ranged from 25 to 50 milliliter(ml), with a median of 32.0 ml(28.5, 36.5). The number of fluoroscopic images per screw ranged from 14 to 20 times, with a median of 17.0 times (15.0, 18.5). According to the Matta evaluation, pelvic fracture reduction was excellent in 16 cases and good in 1 case. Complete weight-bearing walking occurred between 83 and 91 days, with a median of 86 days (85, 88). The healing time for fractures ranged from 12 to 14 weeks, with a median of 13 weeks (12, 13). The placement of the sacroiliac screws was classified as class I in 16 cases and class II in 1 case. One month after the operation, the Majeed score ranged from 35 to 39 points, with a median of 37 (36, 38). One month after the operation, the VAS score ranged from 2 to 3 points, with a median score of 3.00 points(2.00, 3.00). At one month post-operation, hip extension-flexion ranged from 98° to 105°, with a median of 120.0° (119.0, 121.5). At 1 month after surgery, the hip internal-external rotation ranged from 53° to 60°, with a median of 79.00 °(78.00, 80.50). At the last follow-up, the Majeed score ranged from 74 to 77 points, with a median of 76.00 points(75.00, 76.00). The VAS score at the last follow-up ranged from 0 to 2 points, with a median of 1.00 points(1.00, 1.00). The hip extension-flexion ranged from 147° to 149° at the last follow-up, with a median of 148 °(148, 149). The hip internal-external rotation at the last follow-up ranged from 88° to 91°, with a median of 90.00° (89.00, 91.00). In the manual group, the total operation time ranged from 106 to 154 minutes, with a median of 113.50 minutes (109.75, 117.50), while the placement time for a single sacroiliac screw varied from 49 to 56 minutes, with a median of 52.50 minutes (51.00, 54.25). Blood loss ranged from 75 to 110 ml, with a median of 84.5 ml (79.75, 87.25). The number of fluoroscopy images per screw ranged from 33 to 41 times, with a median of 36.5 times (35.75, 39.00). According to the Matta evaluation, pelvic fracture reduction was rated as excellent in 10 cases and good in 8 cases. Complete weight-bearing walking ranged from 84 to 100 days, with a median of 96 days(95, 97). The fracture healing time ranged from 13 to 20 weeks, with a median of 19 weeks(18, 19). The sacroiliac screw was placed in class I in 11 cases and class II in 7 cases. The Majeed score ranged from 25 to 29 points one month after the operation, with a median of 27.00 points(26.00, 28.00). One month after the operation, the VAS score ranged from 3 to 4 points, with a median of 4.00 points(3.00, 4.00); the hip flexion-extension ranged from 98° to 105°, with a median of 101.50°(99.75, 103.25); and the hip internal-external rotation ranged from 53° to 60°, with a median of 57.00°(55.00, 58.25). At the last follow-up, the Majeed score ranged from 74 to 77 points, with a median of 75.50 points(75.00, 76.00). The VAS score at the last follow-up ranged from 0 to 2 points, with a median of 1.00 points(1.00, 1.00). At the last follow-up, hip

extension and flexion ranged from 147° to 149°, with a median of 149° (148, 149). At the last follow-up, hip internal and external rotation ranged from 88° to 91°, with a median of 89.50° (89.00, 90.25). All operations were performed by the same surgeon. All enrolled patients agreed to the surgical treatment plan and signed informed consent. This study was approved by the Ethics Committee of Fengfeng General Hospital of North China Medical Health Group.

1.3 Surgical Methods

1.3.1 Guide Plate Group: We collected imaging data from enrolled patients and utilized Mimics processing software for preoperative digital planning. Patient CT data was segmented and reconstructed based on the injury's characteristics, resulting in a three-dimensional model. Used 3D printing to create individualized intraoperative guide plates. Performed intravenous combined general anesthesia, accurately positioned and guided the surgical operation according to the shape and size of the 3D printed template. Based on the preoperative planning results, performed internal and external rotation reduction of the posterior pelvic ring fracture, achieving optimal fracture reduction in three dimensions, with the option to place a cushion in the lumbar region, combined with intraoperative C-arm X-ray lateral fluoroscopy positioning assistance to determine the screw insertion path, followed by routine disinfection and draping. We made a small incision to insert the preoperatively printed 3D guide plate and then placed guide pins according to its angle. The C-arm X-ray machine confirmed the proper position of the guide pins, and sacroiliac screws were inserted along the guide pins, followed by layered suturing of the incision.

1.3.2 Manual Group: The anesthesia plan and intraoperative position were the same as above. Utilized a traction table for reduction, followed by manual screw placement based on intraoperative C-arm X-ray fluoroscopy results. After satisfactory positioning, the incision was sutured in layers.

1.4 Postoperative Management

All patients underwent intravenous patient-controlled analgesia for postoperative pain management, and were administered antibiotics, specifically Cefuroxime. To prevent thromboembolic complications, low molecular weight heparin sodium was provided for anticoagulation during the first week after surgery. Patients were actively encouraged to participate in early quadriceps strength training and hip-knee joint functional exercises to promote recovery. Regular follow-up appointments were arranged to assess progress and establish individualized weight-bearing timelines based on the results of re-examinations.

1.5 Evaluation Indicators

The study recorded perioperative data, which included operation time, per screw insertion time, blood loss and the number of X-ray fluoroscopy procedures. Clinical outcomes were evaluated based on full weight-bearing activity time, fracture healing time, the visual analogue scale (VAS) for pain, hip flexion-extension range of motion (ROM), hip internal-external rotation ROM, and the Majeed score [8]. According to Majeed's pelvic work, scores ranging from 85 to 100 points are classified as excellent, 70 to 84 points as good, 55 to 69 points as fair, and scores below 55 as poor. Imaging examinations were performed to evaluate pelvic fracture reduction using the Matta scoring criteria [9]. A fracture displacement of less than 4 mm was classified as anatomical reduction (excellent), 4-10 mm as satisfactory reduction (good), 10-20 mm as acceptable reduction (fair), and more than 20 mm as unsatisfactory reduction (poor). The status of fracture reduction and the time taken for fracture healing were recorded. Evaluated screw position using the Gras classification [10]: Class I: safely placed, screw completely within cancellous bone; Class II: safely placed, screw in contact with cortical bone; Class III: screw misplacement, screw penetrates cortical bone.

1.6 Statistical Analysis

Statistical analysis was performed using SPSS 26.0 software. Descriptive statistics were applied to both continuous and categorical variables. For continuous variables that exhibited normal distributions, the results were summarized using the mean and standard deviation. In contrast, continuous variables that did not follow a normal distribution were summarized using the median and interquartile range. Categorical variables were represented as frequencies along with their corresponding composition ratios. Following the testing process, it was found that none of the

continuous variables adhered to a normal distribution. Consequently, the rank sum test was selected for these variables based on their distribution characteristics, while categorical variables were compared using the exact probability method.

2 Conclusion

Both groups of surgeries were successfully completed, and all postoperative incisions healed without infections or complications. Bone healing occurred in both surgical groups. There were statistically significant differences ($P < 0.05$) between the manual group and the other group in several areas: the number of intraoperative fluoroscopy, duration of surgery, time for single screw placement, intraoperative blood loss, and screw positioning. There were also statistically significant differences in the ability to fully bear weight and the duration of bone healing after surgery ($P < 0.05$). One month after surgery, comparisons of the pelvic Majeed score excellent rate, hip internal-external rotation range, hip extension-flexion range, and VAS score revealed statistically significant differences ($P < 0.05$). The Matta scoring criteria for evaluating pelvic fracture reduction displayed statistically significant differences between the two groups ($P < 0.05$). During the final follow-up, comparisons of the pelvic Majeed score excellent rate, hip internal-external rotation range, hip extension-flexion range, and VAS score indicated no statistically significant differences ($P > 0.05$). See Tables 2 ,3 and 4.

Tabel 2

	Operation Time(minutes)	Single Screw Placement Time(minutes)	Blood Loss(ml)	The Number of Fluoroscopy per Screw During Operation(times)	Matta Evaluated the Reduction of Pelvic Fractures（good/excellent）	Screw Position Classification(I/II)	Completely Weight-bearing Walking(days)	Fracture Healing Time(weeks)
guide plate group	81.00（80.00,85.00）	30.00（29.00,31.50）	32.00（28.50,36.50）	17.00（15.00,18.50）	1/16	16/1	86 (85,88)	13 (12,13)
manual group	113.50（109.75,117.50）	52.50（51.00,54.25）	84.50（79.75,87.25）	36.50（35.75,39.00）	8/10	11/7	96 (95,97)	19 (18,19)
Z	-5.057	-5.064	-5.055	-5.066			-5.066	-5.137
P	＜0.001	＜0.001	＜0.001	＜0.001	0.018	0.041	＜0.001	＜0.001

Tabel 3

	Cases	VAS(points)		*Z*	*P*	Majeed(points)		*Z*	*P*
		One Month	Last Follow-up			One Month	Last Follow-up		
guide plate group	17	3.00（2.00，3.00）	1.00（1.00，1.00）	-5.119	＜0.001	37.00（36.00,38.00）	76.00（75.00,76.00）	-5.031	＜0.001
manual group	18	4.00（3.00,4.00）	1.00（1.00,1.00）	-5.387	＜0.001	27.00（26.00,28.00）	75.50（75.00,76.00）	-5.189	＜0.001
Z		-4.319	-0.355			-5.089	-0.387		
P		＜0.001	0.722			＜0.001	0.699		

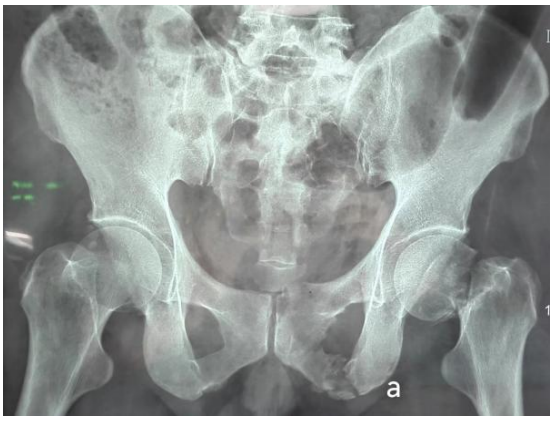
Tabel 4

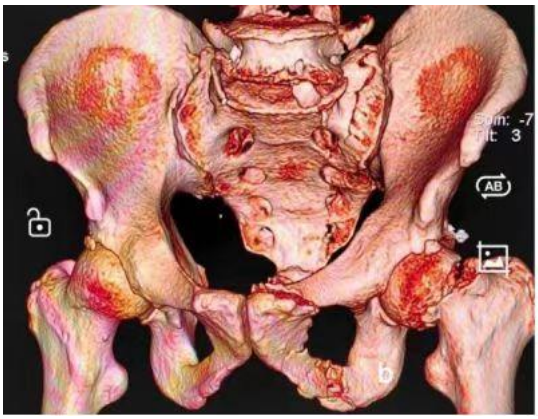
Cases	Extension-flexion	*Z*	*P*	Internal-outward Rotation	*Z*	*P*

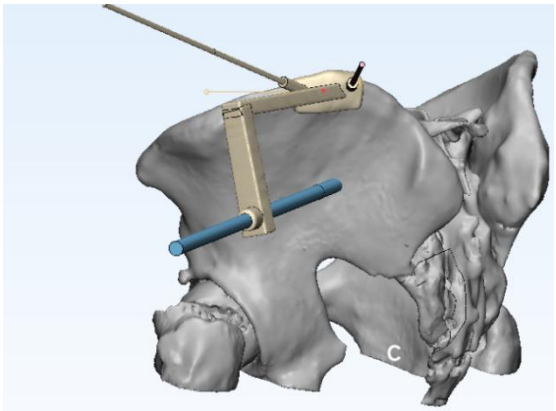
		ROM(°)				ROM(°)			
		One Month	Last Follow-up			One Month	Last Follow-up		
guide plate group	17	120.00（119.00,121.50）	148（148,149）	-5.054	＜0.001	79.00（78.00,80.50）	90.00（89.00,91.00）	-5.058	＜0.001
manual group	18	101.50（99.75，1.03.25）	149（148,149）	-5.205	＜0.001	57.00（55.00,58.25）	89.50（89.00,90.25）	-5.170	＜0.001
Z		-5.066	-0.465			-5.071	-0.743		
P		＜0.001	0.642			＜0.001	0.458		

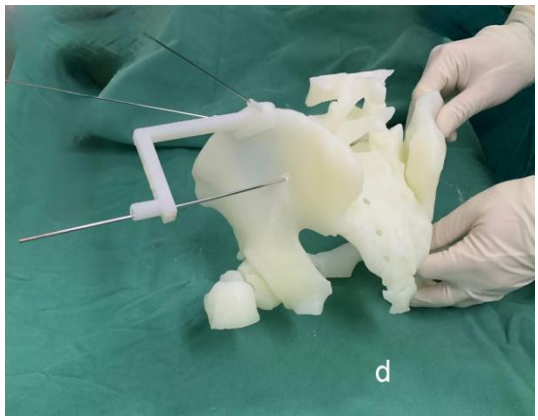
3 Typical Cases

A 56-year-old male patient was admitted for surgery seven days following a car accident. During the accident, sacroiliac screws were inserted with the assistance of a 3D-printed guide, and an external pelvic fixator was applied to provide stabilization. The external fixator was subsequently removed three months post-surgery.









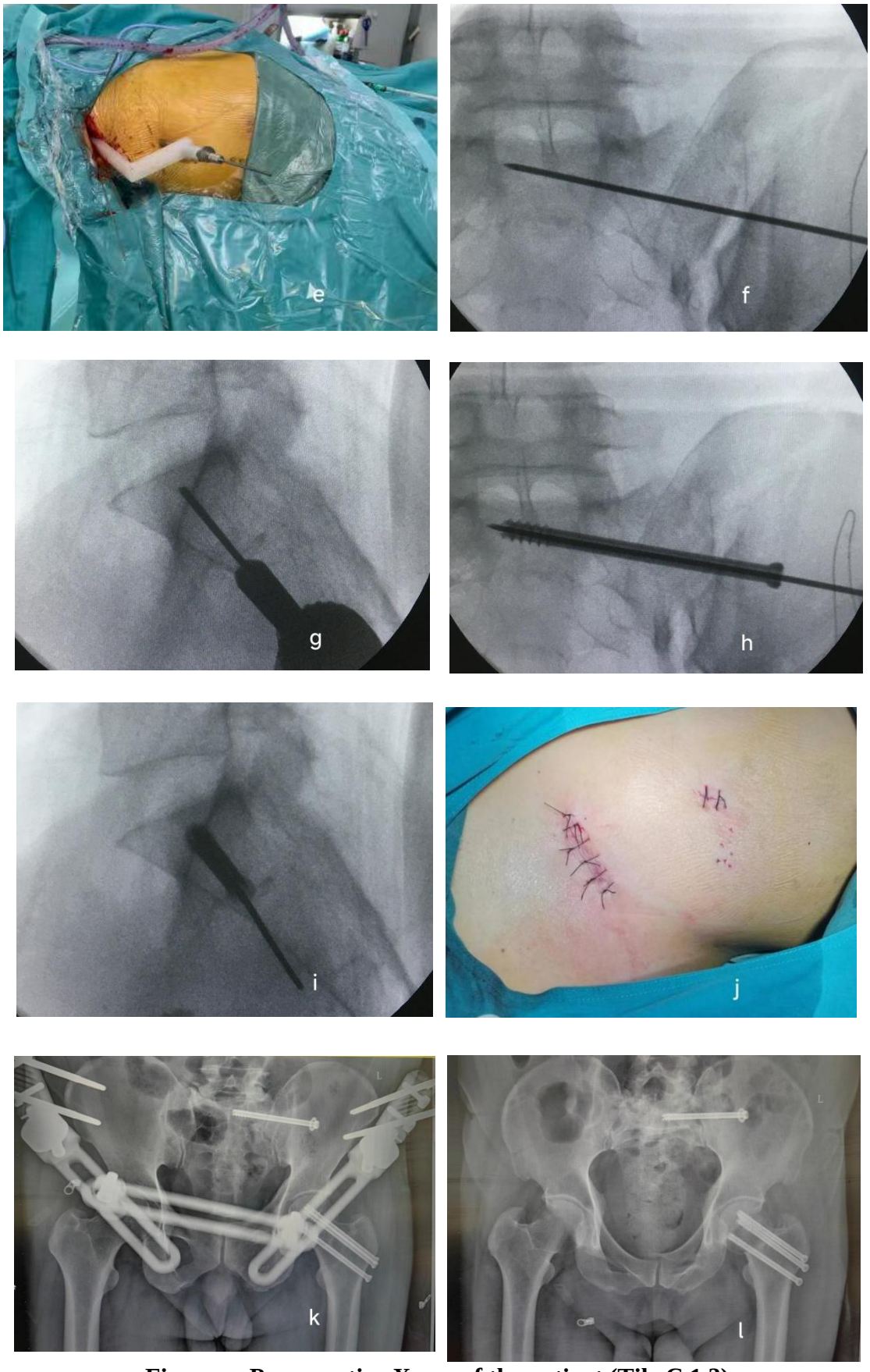


Figure a: Preoperative X-ray of the patient (Tile C 1.3)
Figure b: Preoperative 3D reconstruction of the pelvis
Figure c: Guide plate design
Figure d: Verification of guide plate feasibility on the pelvic model
Figure e: Placement of the guide plate during surgery

Figure f: Guide pin insertion in the anteroposterior view
Figure g: Guide pin insertion in the lateral view
Figure h: Screw insertion in the anteroposterior view
Figure i: Screw insertion in the lateral view
Figure j: Incision at the end of surgery
Figure k: Postoperative anteroposterior X-ray of the pelvis
Figure l: Anteroposterior X-ray after removal of the external pelvic fixator three months after surgery.

4 Discussion

Injury to the sacroiliac joint complex is a common orthopedic condition. Research indicates that the sacroiliac joint is a crucial link between the spine and lower limbs, significantly influencing patients' quality of life and daily activities. Various causes such as trauma and osteoarthritis can lead to dysfunction of the sacroiliac joint, resulting in pain and movement limitations for patients [1]. Currently, numerous treatment methods exist for injuries to the sacroiliac joint complex, yet minimally invasive techniques remain the preferred option [11-13]. Options for minimally invasive treatment include 3D-printed guides, robotic assistance, and navigation systems for sacroiliac screw placement [14-21]. Nevertheless, the high costs associated with robotics and navigation systems impede their use in small to medium-sized hospitals. The relatively low cost of 3D-printed guides, along with their applicability in telemedicine, presents certain advantages. Through minimally invasive surgery, satisfactory outcomes can be achieved for sacroiliac joint complex injuries, with indicators such as blood loss, intraoperative fluoroscopy frequency, and surgical time all being superior to manual screw placement. In comparisons of treatment plans, the 3D-printed guide group significantly outperformed the manual screw placement group in terms of intraoperative fluoroscopy frequency and screw placement time, indicating that 3D-printed guides can effectively reduce radiation exposure and surgical time, which has positive implications for lowering the risk of postoperative complications [22]. Moreover, studies indicate that shorter surgical times may lead to quicker postoperative recovery, suggesting that precise surgical techniques can enhance overall treatment outcomes [23]. In the assessment of side effects, neither group experienced severe complications, indicating that the application of 3D-printed guides is safe. Compared to the manual screw placement group, the 3D-printed group had significantly less intraoperative blood loss, suggesting that this technology may play an important role in reducing surgical risks [24]. Furthermore, the research found that monitoring and managing postoperative complications is an important strategy for improving patient recovery, which has practical significance for reducing the incidence of postoperative complications [25]. Finally, in terms of prognostic evaluation, the 3D-printed guide group performed better in assessing fracture reduction quality and functional recovery, indicating its potential advantages in clinical applications. The results showed that the Majeed score for the 3D-printed group was significantly higher than that of the manual screw placement group, providing strong evidence for the future promotion of 3D printing technology in clinical practice [26]. This suggests that the widespread adoption of 3D printing technology will enable grassroots medical units to implement treatments more effectively, thereby enhancing overall treatment outcomes and significantly improving patients' quality of life [27].

The primary limitations of this study include a small sample size and the lack of a prospective randomized controlled trial design. A small sample size can lead to insufficient statistical significance, which in turn limits the generalizability of the findings. Additionally, the absence of a randomized controlled trial raises concerns about potential selection bias, which may compromise the reliability of the results. Although efforts were made to control for confounding variables, there may still be other unaccounted factors that could affect the outcomes. Therefore, future research should aim to increase the sample size and adopt a prospective design to enhance the scientific rigor and clinical relevance of the study.

In summary, the use of 3D-printed guides for the placement of sacroiliac screws presents significant

benefits for the treatment of sacroiliac joint injuries. These advantages encompass reduced time for screw placement, fewer fluoroscopy sessions required during surgery, decreased blood loss, and enhanced recovery post-surgery. The findings strongly advocate for the integration of these practices into clinical settings, highlighting the promising role of 3D printing technology in orthopedics. As this technology gains traction, it is anticipated that smaller medical facilities will successfully adopt these cutting-edge treatment strategies, ultimately improving patient outcomes and enhancing overall quality of life.

Declarations

Conflict of Interest: There are no conflicts of interest in the research and writing of this article; funding support did not influence the viewpoints of the article or the statistical analysis and reporting of the objective results of the research data.

Ethics Statement: The research protocol was approved by the Medical Ethics Committee of Fengfeng General Hospital of North China Medical Health Group (No. [2022A01]).

Author Contribution Statement: Hongjun Xu: data collection, paper writing, data analysis; Xiaoyong Yin: research design, surgical operation, article review and revision.

Funding: This work was supported by the Fund of the Fengfeng General Hospital of North China Medical Health Group (Grant numbers 2022JZ0704).

Consent for publication: The authors confirmed that human research participants provided informed consent for publication of the images in typical cases.

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