Comparison of three-dimensional navigation-guided percutaneous screw and minimally invasive percutaneous plate for ZoneⅢ sacral fractures

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Research Article

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Abstract

Purposes The aim of surgical treatment for Zonesacral fractures is to rebuild the stability of the pelvis and prevent complications. Iliosacral screw and minimally invasive percutaneous plate all can used in Zonesacral fractures. Screw fixation under 3D navigation was increasingly adopted to improve surgical accuracy and safety. 3D Navigation is more accurate, has shorter surgical time, and has less radiation exposure than conventional X-ray in sacral fractures fixation. Therefore, this study aimed to compare the efficacy of percutaneous iliosacral screw fixation under 3D navigation with minimally invasive percutaneous plate fixation in the treatment of Zonesacral fractures.

Methods Records of patients with Zonesacral fractures were extracted from the case system. Patients with 3D-navigation-guided percutaneous screw fixation (A fixation group) and minimally invasive percutaneous plate (B fixation group) were included. Patients’ injury severity score (ISS), operative time, intra-operative blood loss, length of hospital stay, follow-up time, time to weight bearing, time to clinical healing, and complications were recorded. Matta criteria were used to assess fracture reduction outcomes. Functional outcomes were assessed using the Majeed grading system. X-rays were used to assess fracture displacement and healing.

Results Thirty-five patients in group A and twenty-nine patients in group B were included in this study. Operative time, intra-operative blood loss, length of hospital stay were lower in the A fixation group than in the B fixation group. No significant differences were found between the two groups in ISS, time from admission to operation, time to weight bearing, time to clinical healing, Matta scores, or Majeed scores at follow-up.

Conclusions Based on the results of this study, we conclude that these two methods can achieve satisfactory clinical results in the treatment of Zonesacral fractures. 3D-navigation-guided percutaneous screw fixation has a faster operative time, less blood loss, and shorter hospital stay. In clinical work, we suggest a good option for the treatment of Zonesacral fractures with percutaneous iliosacral screws under 3D-navigation. It is also suitable for patients with vertical displacement and dysmorphic sacral, with careful and adequate preoperative evaluation preplanning.

Introduction

Sacral fractures are usually caused by high-energy trauma, accounting for 30% of the pelvic ring injury, often require operative stabilization[1–3]. Sacral fractures are classified according to Denis: involving the sacrum lateral to the foraminal line (Zone ii), involving the foramina (Zone i) or involving the sacral canal(Zone iii)[2]. According to reports, Zonesacral fractures account for 34–47.5% of sacral fractures[2, 4]. Denis originally described the impact of the fracture zone on neurological deficits and prognosis, with Zonesacral fractures major injury nerve root S1[2]. The goal of surgical intervention is to provide adequate stability for early activity and to avoid malunion. Currently, minimally invasive percutaneous plate[5–6], Lumbopelvic Fixation[7–8], minimally invasive adjustable plate[9], iliosacral screw [1,10–11], trans-
sacral screws⁸ and pedicle screws connected to a transverse rod¹² are commonly used in Zone II sacral fractures. Currently, iliosacral screws and minimally invasive percutaneous plate are the most popular used for the treatment of Zone II sacral fractures. However, IS screw may lead to serious complications, such as injury to the cauda equina, sacral nerve or blood vessels due to screw misplacement. Therefore, some scholars have proposed 3D-navigation-guided percutaneous screw, which has less screw placement time, improves screw placement safety, less intraoperative radiation, and can achieve precise screw placement. However, there are few reports comparing the 3D-navigation-guided percutaneous screw with the minimally invasive percutaneous plate for Zone II sacral fractures. Therefore, we compare the efficacy of two types of internal fixation to provide a more effective treatment for this type of fracture.

**Materials And Methods**

**Patient screening and selection**

The inclusion criteria were
1. age ≥ 18 and ≤ 70 years
2. Zone II sacral fractures
3. Patients with satisfactory Closed reduction
4. Treatment of Zone II sacral fractures by the three-dimensional navigation-guided percutaneous screw and minimally invasive percutaneous plate
5. at least twelve months of follow-up
6. No preoperative symptoms of nerve damage.

The exclusion criteria were
1. age < 18 or > 70 years
2. Patients with rupture in the area of the sacroiliac screw access point
3. serious multiple injuries
4. Combination of severe cardiovascular disease, unable to tolerate surgery

We searched the medical system records for patients with Zone II sacral fractures who were treated with the 3D-navigation-guided percutaneous screw and minimally invasive percutaneous plate. The patient records search periods were from January 2015 to March 2021 for the A fixation group and from January 2011 to December 2015 for the B fixation group.

Table 1

**Comparison of the general situation between two groups.**
<table>
<thead>
<tr>
<th>Variable</th>
<th>A fixation group (n=35)</th>
<th>B fixation group (n=29)</th>
<th>t/chi-square</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>44.51±15.71</td>
<td>39.89±12.78</td>
<td>1.271</td>
<td>0.208</td>
</tr>
<tr>
<td>Gender (men/women)</td>
<td>16/19</td>
<td>15/14</td>
<td>0.229</td>
<td>0.632</td>
</tr>
<tr>
<td>Fracture type according to Tile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tile B2/B3 C1/C2/C3</td>
<td>6/4 11/5/9</td>
<td>3/4 14/6/2</td>
<td>5.390</td>
<td>0.250</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic accidents/Fall from height/Crush</td>
<td>21/11/3</td>
<td>16/7/6</td>
<td>3.212</td>
<td>0.201</td>
</tr>
</tbody>
</table>

**Surgical strategy and technique**

After the patient’s vital signs were stabilized, the relevant preoperative examination was actively improved to clarify the diagnosis and injury. For patients with the significant longitudinal displacement of the posterior ring of the pelvic, closed reduction was achieved by traction. After traction, anteroposterior radiographs of the pelvis were taken to check the quality of the closed reduction, and the following operations were performed only if the closed reduction was satisfactory.

**A fixation group** The patient is usually placed in the supine position. The tracer is fixed at the contralateral anterior superior iliac spine and the navigation device is registered and activated. The field is routinely disinfected and towed. The pelvis of each patient was scanned by CT and data were transferred to a 3D navigation system (Stryker, USA) to provide a 3D image on the screen. After connecting the drill sleeve guided and the guide needle, the guide needle was placed at the preoperative marked entry point, and the position and direction of the guide needle were continuously adjusted. When the virtual guide needle was observed to avoid the sacral foramina and the sacral canal, the guide needle is slowly drilled through the iliac bone and sacroiliac joint to the appropriate depth. Next, 6.5-mm cannulated titanium screws with washers were inserted and tightened sequentially through the inserted guide pins, and final X-rays were checked.

**B fixation group** The patient was placed in the prone position and routinely disinfected and towed. Bilateral posterior superior iliac spine as the center of the inferior and superior incision. The skin and subcutaneous tissue are incised to the periosteum and the soft tissue near the periosteum is dissected to expose the site of the fracture. A deep subfascial tunnel leading to the contralateral side is prepared with a chisel. After shaping, the plate was slid into the prepared groove, crossing the bilateral sacroiliac joints under the deep fascia with the plate located below the S1 spine. After predrilling, the hole positioned above the iliac crest was fixed with a 3.5-mm cortical screw in each iliac wing.
Postoperative antibiotics were given to prevent infection and heparin anticoagulation to prevent deep vein thrombosis in the lower extremities. On the second day after surgery, fluoroscopy—anteroposterior, inlet, and outlet radiographs—and CT were examined. The patients were encouraged to perform active and passive exercises as long as the pain could be tolerated, 3-4 days after the operation. After the operation, the patient was asked to have a regular outpatient review, and the time of weight-bearing on the ground was decided according to follow-up radiography.

**Follow-up**

All patients were followed up for a minimum of 12 months. The main follow-up was through outpatient review and telephone follow-up. Follow-ups were done and pelvic radiographs were taken to evaluate the reduction and the osseous union every month for the first six months and every half year thereafter. Functional outcomes were assessed using the Majeed grading system. Radiographs were used to assess healing and fracture displacement.

<table>
<thead>
<tr>
<th>Variable</th>
<th>A fixation group(n=35)</th>
<th>B fixation group (n=29)</th>
<th>t/chi-square</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISS</td>
<td>24.54±7.12</td>
<td>21.68±6.88</td>
<td>1.619</td>
<td>0.110</td>
</tr>
<tr>
<td>Operative time (mins)</td>
<td>89.22±38.55</td>
<td>132.58±57.22</td>
<td>-3.605</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Intra-operative blood loss (ml)</td>
<td>171.85±311.33</td>
<td>475.86±361.16</td>
<td>-3.617</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Length of hospital stay (days)</td>
<td>13.48±2.80</td>
<td>19.00±3.56</td>
<td>-6.929</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Follow-up time (months)</td>
<td>14.42±1.57</td>
<td>14.79±1.37</td>
<td>-0.975</td>
<td>0.333</td>
</tr>
<tr>
<td>Time from admission to operation(days)</td>
<td>8.20±2.99</td>
<td>8.44±2.18</td>
<td>-0.371</td>
<td>0.711</td>
</tr>
</tbody>
</table>

**Matta evaluation criteria**

<table>
<thead>
<tr>
<th>Excellent/good/poor</th>
<th>22/10/3</th>
<th>19/8/2</th>
<th>0.080</th>
<th>0.961</th>
</tr>
</thead>
</table>

**Majeed score**

<table>
<thead>
<tr>
<th>Excellent/Good/Moderate/Bad</th>
<th>25/9/1</th>
<th>20/7/2</th>
<th>0.581</th>
<th>0.748</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to weight bearing (weeks)</td>
<td>8.07±0.63</td>
<td>8.20±0.64</td>
<td>-0.824</td>
<td>0.413</td>
</tr>
<tr>
<td>Time to clinical healing (weeks)</td>
<td>3.54±0.28</td>
<td>3.46±0.30</td>
<td>1.013</td>
<td>0.315</td>
</tr>
</tbody>
</table>
Statistical analysis

Statistical analysis was performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). We assessed whether measurement data were normally distributed using the Kolmogorov-Smirnov test. We then analyzed the data using independent samples T-tests. For frequency data, the chi-square or Fisher's exact test was used. Differences were considered statistically significant if P was < 0.05.

Results

Clinical data

This study included 64 patients with Zonesacral fractures. The A fixation group included 35 patients, admitted between January 2015 and March 2021; The B fixation group included 29 patients admitted between January 2011 to December 2015. According to Tile classification, there were 9 cases of type B2, 8 cases of type B3, 25 cases of type C1, 11 cases of type C2, and 11 cases of type C3. All 64 operations were performed by a single team.

The mean age of patients was 44.51±15.71 years (range 20-70 years) in group A and the mean age of patients was 39.89±12.78 years (range 23-67 years) in group B. 45.71% and 51.72% of patients in groups A and B were male, respectively. Mechanisms of injury included traffic accidents, fall from height injuries, and crush injuries. The most common mechanism was fall from height, which occurred in 50% and 44.90% of patients in the A and B fixation groups, respectively (Table 1).

We also found no significant differences in terms of age, sex, fracture type, ISS, mechanism of injury, and time from admission to surgery between the two groups.

Comparison of operative characteristics between the two groups

There were no neurovascular injuries associated with this procedure. Mean operative times were 89.22±38.55 and 132.58±57.22 min in the A fixation and B fixation groups, respectively (P < 0.001). Mean intraoperative blood loss were 171.85±311.33 and 475.86±361.16 ml in the A fixation and B fixation groups, respectively (P < 0.001). A significant difference was also found in the length of hospital stay, which was 13.48±2.80 days in the A fixation group and 19.00±3.56 days in the B fixation group (P < 0.001; Table 2)
Follow-up, fracture healing and Postoperative complications

Follow-up time was not significantly different between the two groups (14.42±1.57) months in the A fixation group and (14.79±1.37) months in the B fixation group; P = 0.333. We assessed clinical healing based on imaging presentation, signs, and symptoms. Postoperative weight-bearing time was (8.07±0.63) weeks and (8.20±0.64) weeks in groups A and B; P= 0.413. Clinical healing time was (3.54±0.28) weeks and (3.46±0.30) weeks in groups A and B fixation group (P=0.315), respectively. We found no significant differences in weight-bearing time or clinical healing between the two groups. In the A fixation group, 2 patients had screw loosening and no other complications were observed. In our group, there were 6 patients with LSTV and 3 patients with dysmorphic sacral, all of whom were fixed under 3D-navigation without misplacement screw. In the B fixation group, one patient had an incision infection, of which one was superficial and healed after routine dressing changes. One had a deep infection, which healed after debridement and VSD negative pressure suction. In the B fixation group, three patients are slimmer, the plate was removed after 6 months of postoperative because they felt discomfort.

Discussion

The sacral foramina is a weak area of the sacrum, prone to fracture[4]. Zone II sacral fractures are mostly unstable sacral fracture, which requires internal fixation to rebuild the stability of the pelvis and prevent and release the nerve compression[13]. Iliosacral screw fixation and minimally invasive percutaneous plate are the most common fixation methods for zone II sacral fractures in our institution. Chen et al. concluded iliosacral screw fixation and percutaneous plate fixation are suitable for the treatment of Zone II vertical sacral fractures with reliable stability by finite element analysis[14]. Conventional iliosacral screws require repeated fluoroscopy (inlet and outlet radiographs) during placement, which increases the radiation time and has a certain rate of misplacement, with a screw misplacement rate of 2.6%[15]. With the development of science and technology, 3D-navigation technology has been widely used in surgery. The placement of percutaneous screws under 3D-navigation technology has become the future development direction of orthopedics because of the advantages of screw placement is more precise, faster and safer than conventional fluoroscopy.

It is a challenge to placement of iliosacral screw because of its complex anatomy and the occurrence of dysmorphic sacral[16,17]. Standard intraoperative inlet and outlet radiographs are not based on orthogonal coordinates, and therefore making starting point and aim changes by moving perpendicular to the C-arm beam will cause the trajectory to change on both the inlet and outlet views, resulting in repeated fluoroscopy[18]. Inaccurate fluoroscopic angles make it difficult to discern the position of the guide pin relative to the sacral foramina, making screw placement extremely risky. The application of 3D-navigation-guided technology can clearly display the bony structure of the surgical site and visualize the surgical field. The position of the virtual guide wire to the S1 pedicle and vertebral body can be observed
simultaneously in the Axial, sagittal and coronal planes during the operation to facilitate the
determination of the screw entry point, direction and length.

Most sacral fractures are associated with unstable fractures of the anterior pelvic ring injury[1]. In general,
anterior pelvic ring-related injuries include unilateral or bilateral fractures of the inferior and superior pubic
branches, ruptures of the symphysis pubic, and various combinations. Anterior ring fractures that are not
significantly displaced, are minimally displaced, or are satisfactorily resolved by closed reduction can be
treated with intramedullary fixation and an anterior ring external fixation[19]. We use plate fixation in
patients with disruption of the symphysis pubis.

Misplacement of S1 and S2 screws can cause serious complications, with possible damage to nerve
roots or vessels surrounding of the sacrum and the sympathetic chain[17]. The high incidence of
dysmorphic sacral and the altered anatomy of the sacrum complicate the placement of the iliosacral
screw, which is a high-risk factor for screw placement[1, 16]. A lumbosacral transitional vertebra (LSTV) is
a vertebral body which Lengthening of the last lumbar transverse process, with varying degrees of fusion
to the “first” sacral segment. LSTV is common in the general population, with a reported prevalence of 4–
21%[20]. Matityahu et al. used percutaneous iliosacral screw with 3D-navigation to treat dysmorphic
sacral without a case of screw misposition, and achieved satisfactory results[21]. In our group, there were
6 patients with LSTV and 3 patients with dysmorphic sacral, all of whom were fixed under navigation
without misplacement screws. Nonetheless, closed placement of iliosacral screw under navigation with
displaced vertebrae and dysmorphic sacral still requires careful and adequate preoperative evaluation
preplanning.

Vertical fracture of the sacral, often involving the sacral foramina, resulting in a Zone II sacral fracture[22].
Currently, iliosacral screws are commonly used in the treatment of sacral fractures, have proven to be not
totally reliable in the clinic, with the possibility of internal fixation failure in vertically unstable sacral
fractures, with high mortality and frequent morbidity due to pain and malunion[23]. For the disadvantage
of screws, we can place longer screws by 3D-navigation, which can extend from the first sacral body to
the contralateral wing or through the contralateral iliosacral joint (unlocked trans-sacral screws). At the
same time, we can increase the stability of the iliosacral joint by placing S2 screws. In this group, 23
vertically unstable sacral fractures were fixed with 3D-navigation technology (Fig. 3). Three of them had
significant vertical displacement and were fixed with S1 + S2 screw, extending to the contralateral iliac
wing. None of these failures occurred in the patients with redisplacement at an initial reduction or in
patients who were noted to be noncompliant with postoperative instructions. In this study, a total of 23
iliosacral screws were passed through the sacral canal with a mean length of (97.60 ± 6.00) mm. In 2002,
peter et al. compared the length of sacroiliac screws placed under 3D-navigation with those under X-ray
fluoroscopy. The average screw length in the 3D navigation group was 89 mm compared with 57 mm in
the fluoroscopy group, and the screws were placed safely. This was highly significant (P = 0.0001). The
navigation group was able to achieve the longest screw placement within a precise original point of entry
and direction of the drill[24]. The diameter of the S1 pedicle is measured from the sagittal plane of the 3D-
image, which facilitates the accurate selection of screws. It is also possible to place the longest screw on the S1 vertebral body according to the cross-section, especially for zone sacral fractures, the longer the screw is placed on the S1 vertebral body, the greater the fixation force and the stronger the fixation can be obtained.

Screw loosening and breakage are noteworthy problems in the minimally invasive treatment of pelvic fractures, and although screws have been considered biomechanically reliable posterior ring internal fixation, there are still many cases of screw internal fixation failure reported in the literature[22]. In this study, except for two patients in whom iliosacral screw slightly loosening occurred (Fig. 4), no other cases of loosening and fracture of internal fixation were seen. The reasons for their loosening were analyzed: patients were elderly females, the bone density on review suggested severe osteoporosis, vertical instability of the posterior pelvic ring injury were the main causes of internal fixation failure. The patient was advised to maintain bed rest and regular follow-up, no further loosening of the screw. Oberkircher's biomechanical study concluded that the stability of iliosacral screw with cement reinforcement technique was significantly higher than that of screw fixation without cement reinforcement[25]. For elderly patients with osteoporosis, the screw length can be appropriately lengthened or the sacroiliac screw with bone cement can be used to enhance fixation, and functional exercise without weight-bearing can be performed as early as possible after surgery, and the patient's time on the ground can be appropriately extended to avoid the occurrence of screw loosening.

Many scholars have reported the treatment of Zone sacral fracture with percutaneous reconstruction plate with satisfactory results[12, 26]. Percutaneous reconstruction plate fixation has the advantages of time saving, less invasive, few complications and firm fixation[6]. At the same time, it does not compress the sacral foramen, avoiding the risk of neurovascular injury[26]. However, patients may experience skin irritation (especially in slimmer patients), skin necrosis or infection[5]. Kobbe et al. reported three patients who had plates removed for postoperative discomfort and two patients who developed wound infection[5]. In this study, three patients are slimmer, the internal fixation was removed after 6 months of postoperative because they felt discomfort. Therefore, the plates are optimally placed in areas with thick subcutaneous fat. In addition, shaping of the plate is required intraoperative, which increases the operative time[27]. In addition, the plate is not suitable for fixation of bilateral iliac fractures, especially comminuted fractures, but has significant advantages for osteoporotic patients. The operative time, intraoperative bleeding and hospital stay were significantly higher with the plate in this study. In addition, this technique is contraindicated in cases of skin injury or Morel-Lavalleée syndrome[28].

This retrospective comparative study has some limitations. The periodicity of medical record retrieval differed between the two groups. Also, the sample size was relatively small and more cases should be compared using this method to assess efficacy. Second, our study lacked long-term functional outcomes and long-term follow-up, which needs to be a feature of future study. Although all procedures were performed by a single team, the surgeons' surgical experience may have increased over time. Therefore, a performance bias may potentially have been present. However, this is the first comparison of the efficacy
of these two surgical approaches in the treatment of ZoneⅢ sacral fractures. Our findings provide a cornerstone and reference for future randomized clinical trials on this topic.

**Conclusions**

Based on the results of this study, we conclude that both methods achieve satisfactory results in the treatment of DennisⅢ sacral fractures. However, navigation-assisted internal fixation with sacroiliac screw fixation has a faster operative time, less blood loss, shorter hospital stay and is less invasive. In our clinical work, we recommend the use of navigated percutaneous screw as a good option for the treatment of DennisⅢ sacral fractures. It is also suitable for patients with vertical displacement and dysmorphic sacral, with careful and adequate preoperative evaluation preplanning.

**Abbreviations**

3D: Three-dimensional; ISS: Injury severity score

**Declarations**

**Acknowledgments**

Not applicable

**Authors’ contributions**

XL, XP, and XC designed the study. QS and XK followed up with the patients and collected the relevant data. ZW and QS analyzed and interpreted the data. XP, WZ, and GW performed the virtual surgery. XP wrote the manuscript. All authors read and approved the final manuscript.

**Funding**

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**Availability of data and materials**

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**

This study was approved by the ethics committee of the General Hospital of Central Theater Command. All patients signed the informed consent to participate in the study.
Consent for publication

The authors affirm that patients provided informed consent regarding publishing their data and images.

Competing interests

The authors declare that they have no competing interests.

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References


25. Oberkircher L, Masaeli A, Bliemel C, Debus F, Ruchholtz S, Krüger A. Primary stability of three different iliosacral screw fixation techniques in osteoporotic cadaver specimens—a biomechanical


Figures

Figure 1

A 30-year-old male, LSTV patient, injured due to a traffic accident. A. Pre-operative computed tomography (CT) scan; B-C. Intraoperative 3D picture. D. Post-operative radiographs (anteroposterior view) and axial planes views of CT. F. Radiographs taken 6 months post-operatively
Figure 2

A 46-year-old female patient, injured due to a fall from height. A-B. Pre-operative computed tomography (CT) scan; C-D. Post-operative radiographs (anteroposterior view) and axial planes views of CT. E. Incision photos at follow-up. F. Radiographs taken 6 months post-operatively.

Figure 3

A 25-year-old female patient, injured due to a traffic accident. A. Pre-operative computed tomography (CT) scan; B. Post-operative radiographs (anteroposterior view). C. Radiographs taken 3 months post-operatively, screwed firmly in place.
Figure 4

A patient with screw loosening.