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CLINICAL RESEARCH

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# Accuracy of a table-bound reduction and drill guide system for minimally invasive sacroiliac screw placement in cats

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## Abstract

**Objective:** To describe the equipment and accuracy of a table-bound reduction system and three-dimensional (3D) printed drill guide for fluoroscopically guided, minimally invasive sacroiliac luxation (SIL) reduction and stabilization by means of a single iliosacral lag screw in cats.

**Study design:** Retrospective case series.

**Animals:** A total of 17 cats (20 screws).

**Methods:** Medical records of a single institution were retrospectively reviewed for cats that underwent SIL reduction and stabilization as described in the above objective. Postoperative images were assessed for screw positioning, percentage of sacroiliac reduction, sacral width purchase, and craniocaudal and dorsoventral screw angulation.

**Results:** Sacral width purchase was 82.52% ± 10.67. Percentage of sacroiliac (SI) joint reduction was 94.25% ± 8.14. Craniocaudal screw angle was −1.22° ± 3.96. Dorsoventral screw angles was 0.7° ± 3.90. All screws were classed as being positioned within the sacral body (in).

**Conclusion:** Stabilization of SIL in cats by mean of a single iliosacral screw placed minimally invasively using intraoperative fluoroscopy and a table bound reduction system and 3D printed drill guide system, led to screws that were repeatably placed within the sacral body based on either computed tomography (CT) scan assessment or subjective radiographic assessment.

**Clinical significance:** The described technique and equipment allow placement of iliosacral screws in cats with repeatable accuracy.

**Abbreviations:** 3D, three dimensional; CCA, cranio caudal angle; CT, computed tomography; DVA, dorsoventral angle; HU, hounsfield unit; MIO, minimally invasive osteosynthesis; MPR, multiplanar reconstruction; SI, sacroiliac; SIL, sacroilic luxation.

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## 1 | INTRODUCTION

Amongst feline pelvic traumatic injuries, sacroiliac luxation (SIL) has been reported to be the most common injury accounting for 60%–93% of these cases.[1,2] As a consequence of the high-energy trauma required to fracture pelvic bones, and the box-like structure of the pelvis, unilateral SIL are generally accompanied with concomitant pelvic fractures.[3] Concomitant pelvic fractures may or may not occur with bilateral luxations.[2]

Non-surgical management of pelvic fractures may be considered when the patients are ambulatory, the weight-bearing axis is intact, there is limited displacement of non-articular fractures, neurological deficits are minimal, no other concurrent orthopedic injuries are present, associated pain is treatable and pelvic canal narrowing is less than 45%.[1,2,4] Good medium to long term outcome has been reported in cats with SIL managed without surgery if the aforementioned criteria were met.[5]

When surgical treatment of SIL is indicated, screw fixation in lag fashion, via either an open or minimally invasive approach, is the preferred method for SIL stabilization.[6] The technique may be challenging as the average area for adequate screw positioning in cats is less than half a square centimeter.[3] The screw should be seated into the sacral body and engage at least 60% of the sacral width to avoid impingement of the cauda equina or lumbosacral plexus and minimize postoperative loosening, respectively.[6,7]

The use of intraoperative fluoroscopy has demonstrated more precise and consistent sacral screw placement than open reduction and internal fixation and higher rate of optimal screw purchase.[8–11] Other advantages described in the human literature are decreased surgical and hospitalization time, decreased blood loss and postoperative pain.[12,13] Nonetheless, use of fluoroscopy for SIL stabilization presents challenges such as the difficulty in maintaining appropriate sacroiliac (SI) reduction during the procedure, difficulty in maintaining optimal trajectory of the drill and finally the potential radiation exposure of the personnel.

To address the above limitations, a table-bound system has been developed and described in a cadaveric canine study.[14] This system maintains temporary SI reduction and also holds a drill guide in a set position and trajectory. This system negates the requirement to manually maintain reduction or to hold the drill guide, allowing the personnel to step away from the C-arm while fluoroscopic imaging is performed.[14] This system has shown a dorsoventral and a craniocaudal screw angulation of 1.6° ± 1.1 (0.3–3.7) and 1.2° ± 0.6 (0.7–2.1), respectively, and potentially increases accuracy of the iliosacral pilot and glide holes because, once ideal trajectory has been established fluoroscopically, the drill guide is fixed in the ideal set position by the table bound system.[8]

To the authors' knowledge, no study has reported the use of a similar system in cats. The aim of the present study was to retrospectively describe the use and accuracy of a table-bound reduction and drill guide system for fluoroscopy guided minimally invasive SIL stabilization by screw insertion in lag fashion in 17 cats (20 screws) affected by traumatic SIL.

## 2 | MATERIALS AND METHODS

Medical records of a single center (Willows Veterinary Center and Referral Center, Solihull, UK) were retrospectively reviewed for cats treated for SIL.

Inclusion criteria were cats with SIL that underwent minimally invasive fluoroscopically guided surgical stabilization by means of a single screw applied in lag fashion using a table-bound system to maintain SI reduction and to hold the drill guide in the set position and trajectory. Retrieved data were: signalment (breed, age at surgery, weight at surgery), laterality of SIL (right, left or bilateral), presence of other concurrent orthopedic injuries, surgical technique, surgery time, implant utilized (screw diameter, length and use of a washer), pre- and postoperative imaging modalities and perioperative complications. When bilateral SIL was treated, each screw was counted and assessed separately.

### 2.1 | Preoperative care

All patients were treated to ensure their clinical condition was stable before proceeding to SI stabilization surgery. General anesthetic protocols were decided by the anesthetist in charge of the case and varied depending on the individual patient needs and anesthetist preference. Details of the general anesthetic protocols and preoperative care were deemed not to be relevant for the purpose of this study and were not reported. Preoperative imaging modality (pelvic radiographs, computed tomography [CT], or both) was chosen on a case-by-case basis and was ultimately based on the surgeon's preference.

### 2.2 | Instrumentation

The equipment needed for the surgical technique, in addition to what is normally utilized for conventional minimally invasive osteosynthesis (MIO) procedures, included two table bound articulated arms and a three-dimensional (3D) printed drill guide system.

Each articulated arm (articulated stand L-shape and straight, Karl Storz SE & Co, Germany) is secured to the rail at the side of the table by a clamp. An L-shape articulated stand is secured within the rail clamp and connected to a central mechanical clamp that locks all joint junctions. At the proximal end of the stand, the device interface consists of a C-clamp which is used to hold either the reduction pin, reduction forceps or the drill guide (Figure 1).

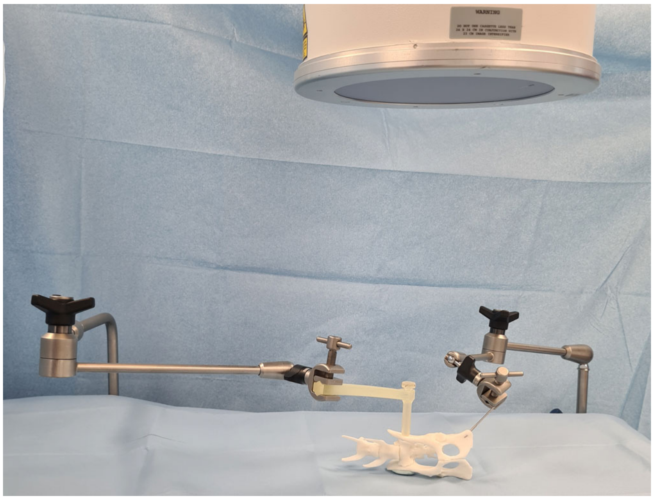

**FIGURE 1** Surgical setup showing the different components of the reduction and three dimensional (3D) printed drill guide system. On the left of the image is the handle with the aiming device insert, connected to an articulated arm. Another articulated arm is visible on the right of the image and maintains reduction.

The 3D printed drill guide system is made of autoclavable, biocompatible, 3D printed radiolucent resin (BioMed Amber resin, FormLabs, Ohio). It is reusable and not patient specific. The components of the 3D printed drill guide system are:

- *The handle*. This has an elongated cuboid shape which is secured at one end to the articulated arm C-clamp. At the opposite end there is a fixed sleeve which can accommodate either the aiming device insert, the 1.8 mm or the 2.4 mm drill guide insert (Figure 2). The sleeve has an internal diameter of 6.7 mm, which is larger than the diameter of a 2.4 mm cortical screw head (i.e., 3.8 mm diameter) and washer (4.7 mm diameter) and also than a 2.7 mm cortical screw head (4 mm diameter) and washer (6 mm diameter). This feature allows placement of the screw and washer through the sleeve, which acts as tissue retractor for the gluteal muscles.
- *The aiming device insert*. This is designed with a sliding fit with the handle's sleeve. The top part of the aiming device contains two orthogonal 0.9 mm diameter stainless-steel K-wires. The bottom part of the aiming device contains a 1 mm diameter stainless-steel sphere (Figure 3). On the fluoroscopy image, when the sphere is superimposed to the crossing point of the K-wires it

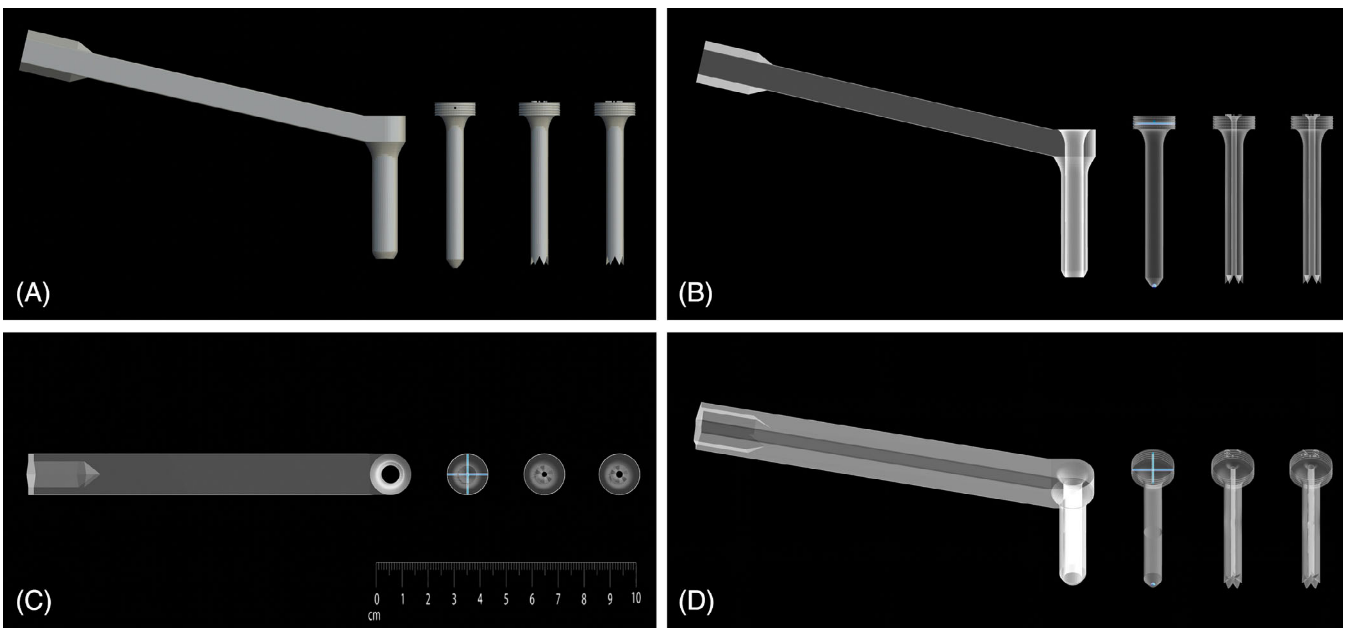


**FIGURE 2** Illustration of the different components of the three dimensional (3D) printed drill guide system. From left to right, handle, aiming device insert (note the crossing K-wires, represented as blue lines at the top, and the stainless-steel sphere, represented as a blue dot, at the bottom), 1.8 mm drill guide insert, 2.4 mm drill guide insert. (A) Opaque illustration viewed from its side. (B) Transparent illustration viewed from its side. (C) Transparent illustration viewed from the top. (D) Transparent illustration viewed from an oblique angle.

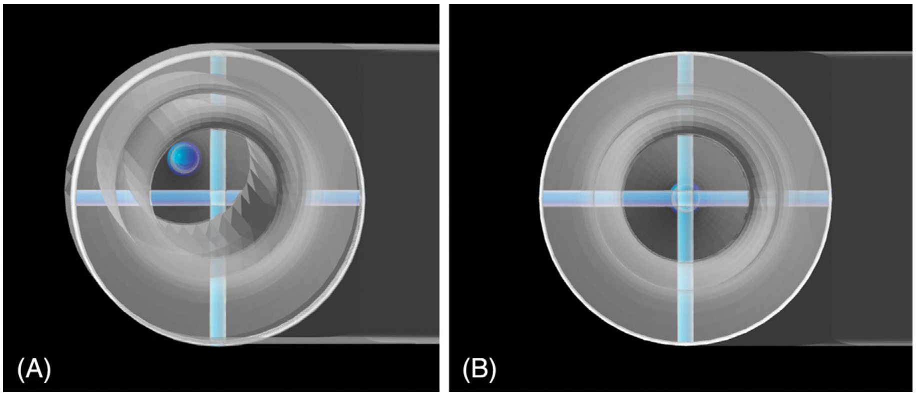


FIGURE 3 Computer-assisted design showing the incorrect orientation of the aiming device (A) where the two orthogonal K-wires (here represented as orthogonal blue lines) do not match with the stainless-steel sphere at the distal tip (here represented as blue point). Appropriate alignment is represented in (B) in which crossing point of the K-wires is superimposed with the stainless-steel sphere.

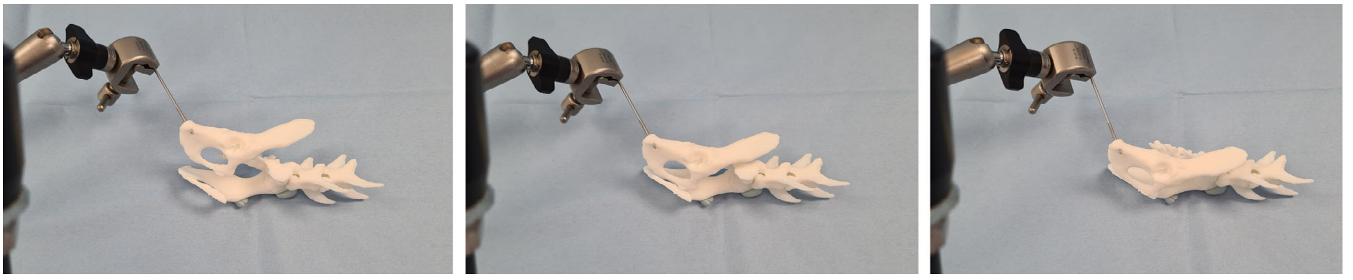

FIGURE 4 Simulation of sacroiliac reduction in a three dimensional (3D) printed feline skeleton. A positive-threaded pin inserted in the ischiatic tuberosity is connected to the articulated arm. The arm is manipulated until correct reduction is achieved, which is confirmed fluoroscopically.

indicates that the aiming device is aligned with the x-ray beam (Figure 3).

- *The drill guide inserts*. These are also designed with a sliding fit with the handle's sleeve. The body of the drill sleeve guides is hollow to accommodate either a 1.8 mm or a 2.4 mm drill bit. The distal end, which contacts the ilium surface during drilling, is serrated to increase grip and stability (Figure 2).

## 2.3 | Surgical technique

All procedures were performed by a board-certified surgeon (AB or SPC). All personnel present in theater while fluoroscopy images were acquired, wore appropriate personal protective equipment (i.e., lead gown, lead collar, radiation monitoring badge).

When concurrent pelvic fractures were present, the SIL was treated first to prevent metalwork reducing visibility of the SI joint.

A surgical table (Stille ImagiQ2 C-arm table, Torshälla, Sweden) purpose built for use with fluoroscopy was utilized. This allowed for ±15° of lateral roll, ±25° Trendelenburg and also “float and lock” linear adjustments.

Patients were positioned in lateral recumbency with the affected side uppermost. Positioning aids such as vacuum beanbag positioners, sandbags, foam blocks and foam wedges were used at the discretion of the surgeon. Care was taken to ensure that the pelvis was perpendicular to the operating table, and this was confirmed by using the C-arm (Philips BV Pulsera C-arm Image Intensifier, Koninklijke Philips N.V, Amsterdam, Netherlands) to acquire a preoperative lateral projection of the pelvis. Patients were considered well positioned when there was both accurate overlapping of the L7 transverse processes (roll) and alignment of the end plates of L7 and S1 (yaw). Positioning was adjusted either by moving the patient, adding foam wedges under the patient, or by changing the table positioning. The final skin preparation and draping was done at that stage. The C-arm detector was covered by a sterile plastic film which reduced risk of contamination of the surgical field. A positive-threaded pin of between 1.6 and 2.4 mm diameter, depending on the patient size, was inserted either in the craniodorsal aspect of the iliac wing, or in the ischiatic tuberosity via a small skin incision based on surgeon preference and concomitant fractures. Alternatively, bone holding forceps with serrated jaws were secured via a small skin incision to the ischiatic tuberosity. Sacroiliac reduction was initially achieved by manipulation of the pin or forceps, used as a handle, and then maintained by securing the pin, or forceps, to the table-bound articulated arm which would then be locked in the desired position (Figure 4). Adequate reduction of the SI joint was confirmed with orthogonal fluoroscopic views and subsequent readjustments were performed as needed. At the surgeon's discretion, a temporary K-wire (1.1–1.4 mm diameter) was placed across the SI joint caudal to the intended screw location as additional temporary fixation as described by Tomlinson.[15] A stainless-steel surgical washer, resting on the skin, was used to determine the position of the sacral body as described by Déjardin et al.[14] Once the correct sacral body location was established, a stab incision was made through the skin and the gluteal muscles. Then, the handle of the 3D printed drill guide system was secured to the second table-bound articulated arm. Subsequently, the sleeve, containing the aiming device insert, was positioned into the incision until it contacted the ilium. The handle was manipulated until a satisfactory position and trajectory were achieved and confirmed with fluoroscopy (Figure 5). Satisfactory trajectory and positioning were confirmed when the crossing point of the K-wires and the stainless-steel sphere of the aiming device insert were superimposed over the body of the sacrum. Once positioned appropriately the table-bound articulating arm was locked. Before proceeding to the next step, the fluoroscopic image was checked to ensure the patient was still correctly positioned. If patient malpositioning was identified, this was addressed by adjusting the positioning aids. Conversely, minor adjustments in yaw and roll could be achieved by tilting the C-arm or the surgical table. The aiming device insert was then removed from the sleeve and replaced with the 1.8 mm drill guide insert. Following drilling of a 1.8 mm hole in both ilium and sacrum, the 1.8 mm drill guide insert was replaced with the 2.4 mm drill guide insert and a 2.4 mm glide hole was drilled through the ilium. In cases with bilateral SIL, care was taken to place the first screw as cranial as possible to allow space for the second screw to be placed caudally to the first. Next, with the drill guide insert removed from the handle, a 2.4 mm self-tapping cortical screw, with a washer, was inserted through the device sleeve, into the body of the sacrum and tightened before skin closure (Figure 6). Required screw length was calculated prior to surgery by adding the width of the sacrum to the width of the ilium. A single skin suture was used to close the skin incision.

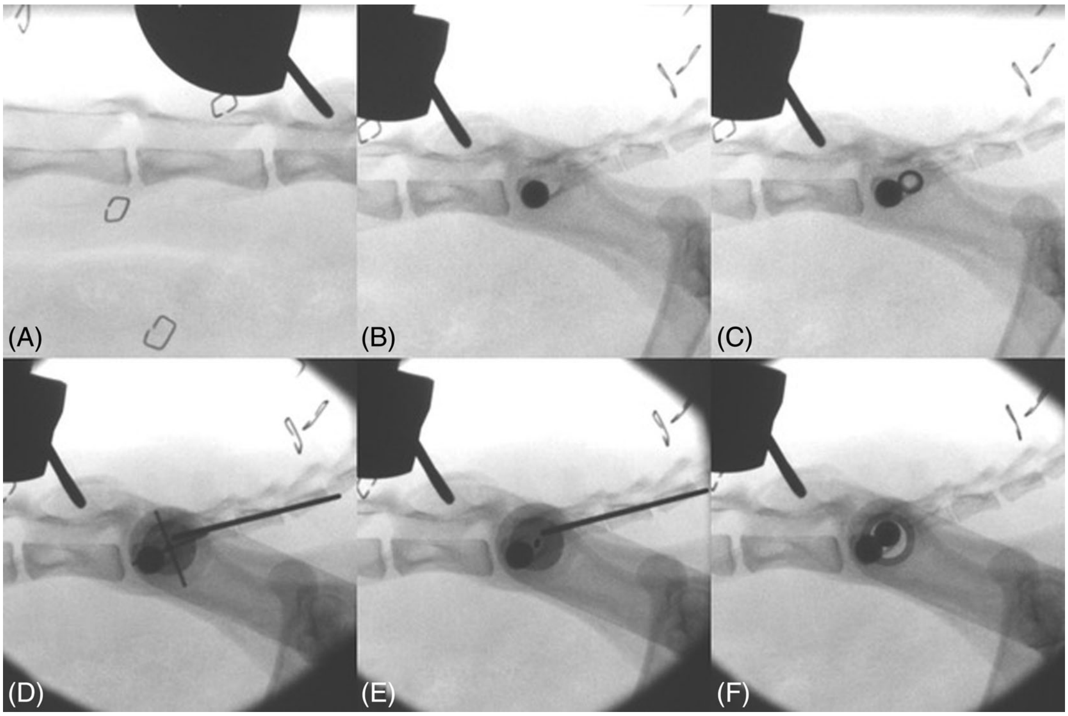


FIGURE 5 Fluoroscopic images showing the steps for placing a second sacroiliac screw in a bilateral case. Correct position of the spine is assessed and adjusted as necessary based on the appearance of the transverse processes of L7. This step is repeated between any manipulation of the spine or pelvis (A). The affected hemipelvis is mobilized and reduced. In this case, a threaded pin place in the dorsal iliac spine is used (B). The area of skin and muscle incision is localized with a washer placed on the skin (C). A temporary sacroiliac K-wire is placed before inserting the handle with the aiming device. Entry point and angulation of the pilot hole are adjusted using the sphere and crosshair of the aiming device. The second screw is placed immediately caudal to the first screw. The aiming device superimposed over the sacral body slightly decreases its visualization on the fluoroscopy image, while its contours remain visible (D). The pilot hole is drilled after exchanging the aiming insert for the first drilling insert. A K-wire is placed in the pilot hole to confirm location and orientation of the pilot hole within the sacrum (E). The glide hole is drilled using the second drilling insert. The drilling insert is removed. A 2.4 mm diameter screw with a washer is inserted through the handle and tightened (F). Please note a degree of asymmetric reduction of the two hemipelves in this case.

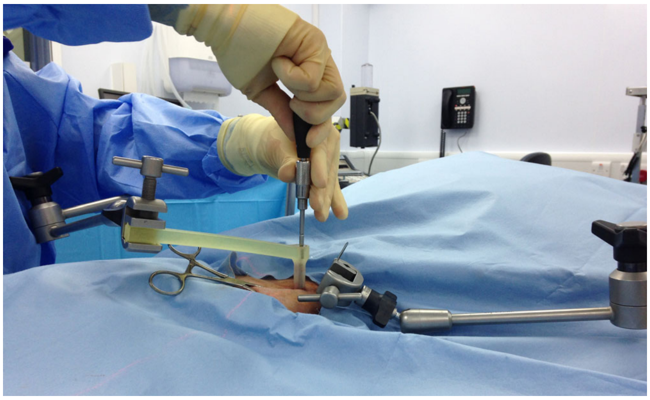

FIGURE 6 Insertion of a cortical screw through the handle which acts as tissue retractor. Please note reduction pin in the iliac wing.

Finally, based on the surgeon's preference, either orthogonal radiographs of the pelvis and/or a CT scan were acquired, to assess SI reduction, screw depth and screw orientation.

## 2.4 | Postoperative evaluation

Postoperative images of the pelvis (either orthogonal ventrodorsal and lateral radiographs or CT scan) were assessed by a board-certified surgeon (SA). When both a postoperative CT scan and radiographs were available, assessment was performed on CT scan. Radiographs was considered appropriately positioned when, on a ventrodorsal projection, the spinous process of L7 bisected the vertebral body and when, on a latero-lateral projection, the transverse processes of L7 were superimposed (Figure 7). CT scan images were viewed using high Hounsfield Unit (HU) windowing. Screw position was assessed on either the radiograph or when available the CT, and subjectively classified as being completely within the sacral body (in), breaching the pelvic canal, spinal canal or L7–S1 intervertebral disk (out) as per Silveira and colleagues.[16] Screws were classed as equivocal if it was not possible to definitively confirm if the screw had or had not exited the sacral body. The percentage of sacroiliac reduction (% SI reduction) and the percentage of sacral width purchase (% sacral width) were measured. To measure percentage of SI reduction the craniocaudal length of the articular surface of the sacral wing in close alignment with the articular surface of the wing of the ilium was measured from ventrodorsal radiographs or MPR CT images. This length was then expressed as a percentage of the total craniocaudal length of the articular surface of the sacral wing. Percentage of sacral width purchase was assessed from postoperative ventrodorsal radiographs or MPR CT scan images. The length of the screw shaft within the sacrum was measured and the depth then expressed as a percentage of the entire width of the sacral body. All above measurements were performed as described by Silveira and colleagues.[16] For patients with radiographs only, caudocranial screw angulation was measured on the ventrodorsal pelvis radiograph. A line was positioned on the longitudinal axis of the sacrum. Screw angulation was measured between a line superimposed with the screw and the perpendicular to the sacral longitudinal axis. (Figure 7). Dorsoventral screw angulation was not measured for patients with postoperative radiographs only. When a CT scan was available for a patient, this was used to measure both craniocaudal and dorsoventral screw angulation as described elsewhere[8,14] and the radiographs (if available) were not used (Figure 8). Positive values were used to indicate screws that aimed cranially or dorsally, and negative values indicated screws that aimed caudally or ventrally.

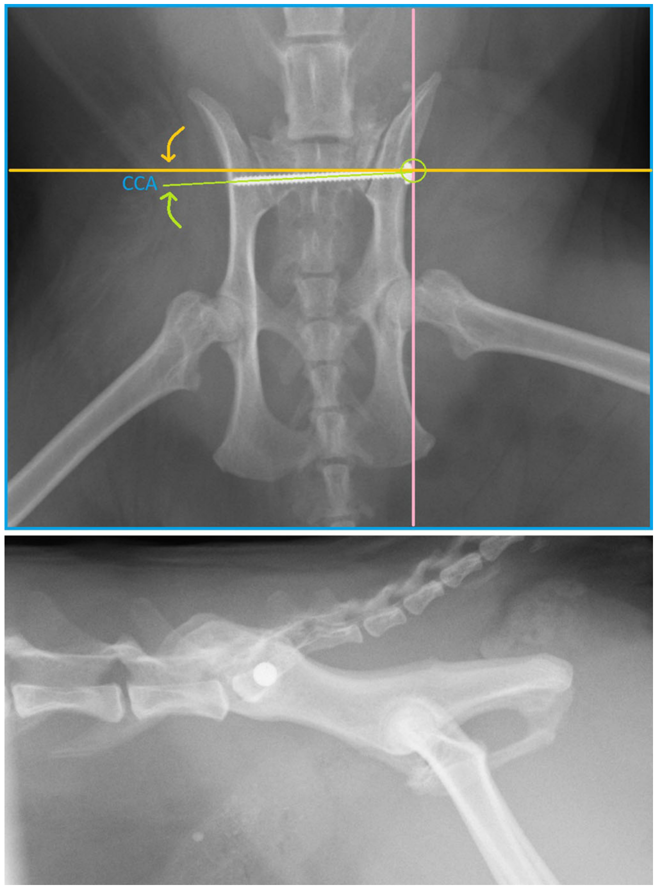


FIGURE 7 Postoperative radiographs of a cat after unilateral sacroiliac (SI) screw placement. The figure also shows how cranial caudal angle (CCA) is calculated. Dorsoventral angle (DVA) is not calculated on radiographs.

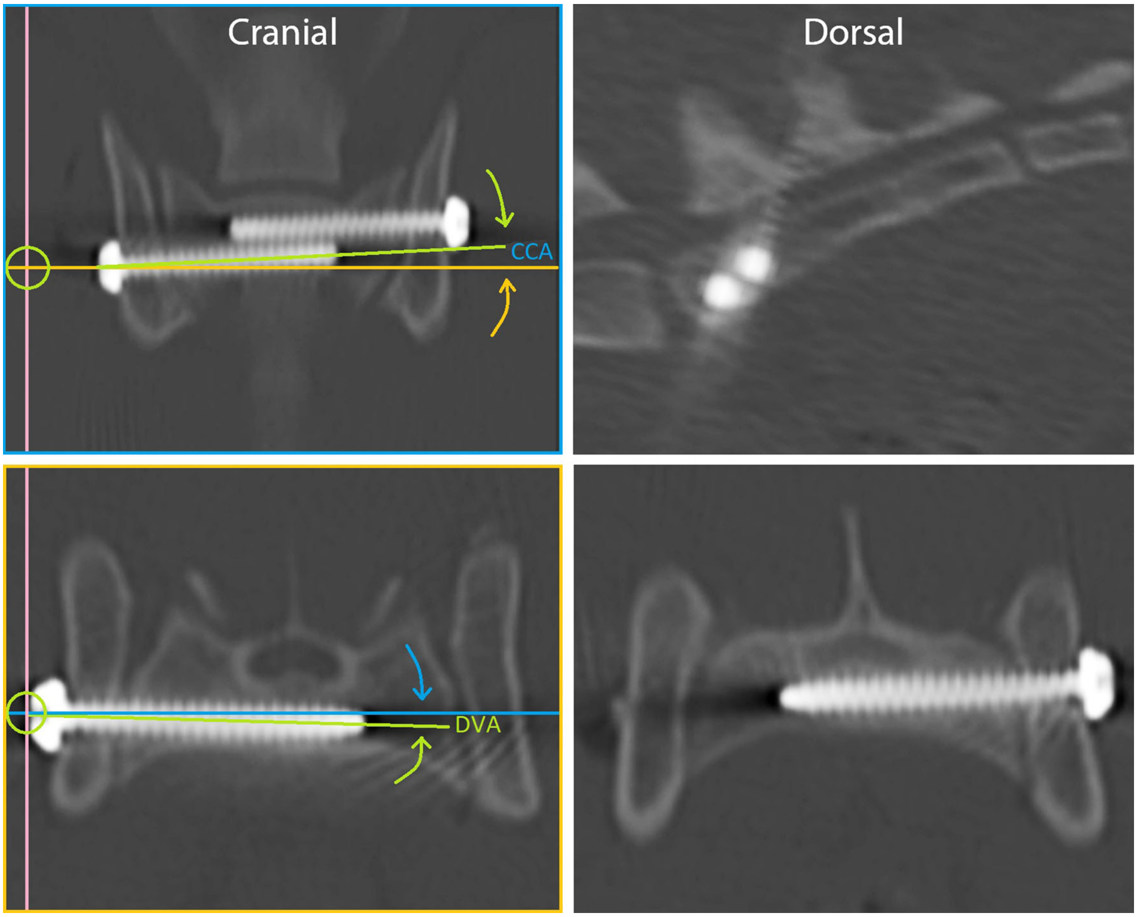


FIGURE 8 Postoperative computed tomography (CT) scan multiplanar reconstruction (MPR) of a cat after bilateral sacroiliac (SI) screw placement. The figure also shows how cranial caudal angle (CCA) and dorsoventral angle (DVA) are calculated.

# 3 | RESULTS

## 3.1 | Study population

A total of 17 cats met the inclusion criteria. The mean age at the time of presentation was 6.03 years ± 4.36 (range, 1–14.2). A total of 11 were neutered males, five neutered females and one entire female. The mean bodyweight was 4.4 kg ± 0.95 (range, 2.93–6.4). The following breeds were reported: Domestic Shorthair ($n = 9$), Burmese ($n = 2$), British Shorthair ($n = 2$), Bengal ($n = 2$), Norwegian Forest ($n = 1$) and Domestic Lynx ($n = 1$).

The distribution of the SIL was eight left side, six right side and three bilateral. A total of 20 screws were therefore evaluated. A total of 16 out of 17 cats had concurrent pelvic injuries including eight pubic fractures, five concomitant sacral wing fractures, three ischiatic fractures, four iliac fractures, three acetabular fractures, three sacrocaudal fracture-luxation, one unilateral hip luxation and one unilateral comminuted femoral fracture. One cat with bilateral sacroiliac luxation had no concurrent pelvic injuries. The mean time from the trauma to the surgery was 2.94 days ±1.63 (range, 1–5).

## 3.2 | Imaging

Preoperatively, 7/17 cats had pelvic radiographs, 6/17 cats had a CT scan of the pelvis and 4/17 cats had both imaging modalities. Postoperatively, 13/17 cats had pelvic radiographs, 2/17 cats had a CT scan of the pelvis and 2/17 cats had both imaging modalities.

## 3.3 | Implants

A total of 19 out of 20 (19/20) screws were 2.4 mm in external diameter with only one screw being 2.7 mm. All screws (20/20) were placed with a washer.

### 3.4 | Intraoperative complications

No intraoperative complications were reported, and all pilot holes were drilled in a single attempt.

### 3.5 | Postoperative evaluation

Screw positioning was assessed on radiographs in 13/20 and on CT scan in 7/20.

A total of 19 screws were classed as being positioned within the sacral body (in). The remaining screw was placed in a patient who had a lumbosacral transitional vertebra; the iliac wing was articulating with L7 and not with S1. For this reason, it was not possible to place the screw within the body of S1 and instead the screw was sited within the body of the sacralized transitional L7. Owing to a deliberate presurgical decision this screw was classed as "in".

Sacral width purchase had a mean of 82.52% ± 10.67 (range, 61–100). Percentage of sacroiliac (SI) joint reduction had a mean of 94.25% ± 8.14 (range, 79.8–100). Craniocaudal screw angle had a mean of −1.22° ± 3.96 (range, −6 to 8). Dorsoventral screw angles had a mean of 0.71° ± 3.9 (range, −5 to 5). Values for individual screws are reported in Table 1.

## 4 | DISCUSSION

Achieving more than 90% of SI joint reduction has consistently been associated with reduced incidence of screw loosening and, therefore, maximal reduction should be pursued.[11,15,17] We report a mean percentage of SI joint reduction of 94.25% ± 8.14 (79.8–100). Our results appear similar to a feline study where screw insertion was performed using intraoperative fluoroscopy and where radiographs used for postoperative assessment, reported a mean SI reduction of 86.6% ± 11.5.[16] In a cadaveric study in cats, also using MIO for SIL repair, the mean percentage of reduction was 98.33% (range, 90–100).[18] It should be noted that challenges related to a clinical setting (i.e., muscle contraction, soft tissue damage, concurrent pelvic injuries or time since injury) can make results

**TABLE 1** A concise overview of the data and relevant statistical measures.

| Number | Laterality | SX time (min) | Postoperative imaging | SP | %SWP | %SIR | CCA | DVA |
|---|---|---|---|---|---|---|---|---|
| 1 | Left | | XR | in | 100 | 100 | −1.8 | |
| 2 | Bilateral>left | | CT | in | 79.6 | 82.1 | 5 | 5 |
| 3 | Bilateral>right | | CT | in | 78.3 | 100 | −5 | −4 |
| 4 | Left | | XR | in | 100 | 100 | −2 | |
| 5 | Right | 60 | XR | in | 88.5 | 100 | −0.8 | |
| 6 | Left | | XR | in | 85.6 | 100 | 2.4 | |
| 7 | Left | | XR | in | 100 | 100 | −2 | |
| 8 | Right | | XR | in | 79.6 | 100 | 7.7 | |
| 9 | Right | | XR | in | 75.2 | 100 | −3 | |
| 10 | Left | 55 | CT + XR | in | 91 | 100 | −3.9 | 2 |
| 11 | Bilateral>right | 65 | CT + XR | in | 71.6 | 100 | −3.4 | 3 |
| 12 | Bilateral>left | 35 | CT + XR | in | 80.2 | 100 | −2.6 | 0 |
| 13 | Right | | XR | in | 70.9 | 85 | −3 | |
| 14 | Right | 75 | XR | in | 78.9 | 79.8 | −2 | |
| 15 | Left | 35 | XR | in | 85.8 | 83.1 | −5.7 | |
| 16 | Left | 65 | XR | in | 69.8 | 86.4 | −2.2 | |
| 17 | Left | 60 | XR | in | 88.4 | 82.6 | −2.1 | |
| 18 | Bilateral>right | 50 | CT | in | 61 | 100 | 8 | 4 |
| 19 | Bilateral>left | 60 | CT | in | 76 | 100 | −6 | −5 |
| 20 | Right | 50 | XR | in | 90 | 86 | −2 | |

Abbreviations: %SIR, % sacroiliac reduction; %SWP, % sacral width purchase; CCA, craniocaudal angle (degrees); CT, computed tomography; DVA, dorsoventral angle (degrees); SP, screw position within sacral body (in, out, equivocal); SX, surgery; XR, radiography.

between a cadaveric and a clinical study difficult to compare. Our results suggest that the technique we describe allows for repeatable and satisfactory SI joint reduction.

A minimum of 60% sacral purchase by the screw is recommended to minimize the risk of implant loosening in dogs and cats.[7] Sacral purchase was above 60% in all our patients with a mean ± SD of 82.52% ± 10.67 (range, 61–100). These results appear similar to the rates previously reported in cats, for both open and minimally invasive techniques (means from 54.6% to 73.0%).[16,19,20]

Our findings showed a mean cranio-caudal screw direction angle of $-1.22° \pm 3.96$ ($-6$ to 8) which compares favorably with a previous study in feline patients with SIL repaired by MIO (mean 4.5°, range, $-16.6$ to $+6.6$).[19] The authors speculate that the drill guide, being locked to the surgical table, helped to maintain more accurately the set drill trajectory.

A total of 16 of 20 screws aimed caudally. The authors feel that caudal screw angulation was related to imperfect pelvis positioning. We suggest that assessing pelvis positioning using orthogonal fluoroscopy rather than vertical fluoroscopy alone may improve patient positioning and screw trajectory. This, however, needs to be assessed in future studies. Although horizontal beam fluoroscopy could temporarily complicate access to the patient, the authors did not perceive this being a significant problem because the C-arm could rapidly be returned to a vertical position when proceeding with the procedure. To facilitate this, vertical beam position was recorded before moving the C-arm to a horizontal beam position. Nevertheless, horizontal scatter radiation and personnel exposure needs to be accounted for before using horizontal beam fluoroscopy.

A temporary SI K-wire was used for three screws out of 20. There was no information in the surgical notes suggesting this was related to instability of the reduction system. While the rigidity of the positioning arms, the size and bone purchase of the reduction pin, and the stability of the patient body and sacrum are crucial factors for stability, the addition of a K-wire is probably not necessary.

The end of the drill guide inserts was designed with serration aimed to improve grip with the lateral surface of the ileum. Because the drill guide insert is free to slide within the handle sleeve, the amount of friction the serration can generate against the ilium might be low. Redesigning the guide with the serration to the end of the sleeve, instead of drill guide insert, might improve stability (as the sleeve is held against the ilium by the articulated arm). The authors decided against this option as the tapered end of the sleeve allows for easy insertion in the gluteal muscles which will likely be made more difficult, with increased soft tissue trauma, if serrations were added.

The articulated arms utilized in this study provide a secure fixation. However, care must be taken to ensure the drill bit is aligned with the drill guide and not leaning against it, otherwise the pilot hole might be drilled with a suboptimal trajectory.

Adequate screw positioning within the sacral body is important to avoid the risk of iatrogenic nerve damage but also to ensure optimal sacral purchase.[15,21] An angle of 90° ± 2 had been recommended in cats as a safe dorsoventral corridor to avoid the risk of ventral breaching by Shales and colleagues.[21] Several studies have shown improved screw positioning and orientation when intraoperative imaging is used.[8,10,16] In a comparative study on SIL repair in cats by open approach, the number of screws correctly positioned within the sacrum was significantly higher in the group that used intraoperative radiology (19/23 screws) compared to the group that did not use it (8 out 17 screws).[16] This compares favorably with our results as all our screws were placed correctly, including the one deliberately placed in the body of a L7 transitional vertebra. In such a location the transitional vertebra has features of both the last lumbar vertebra and first sacral vertebra, and in this patient resulted in the iliac wing articulating with L7 instead of the sacral body, preventing placement of the screw within the sacrum. This was identified at the time of surgical planning and the surgeon elected to place the screw within the vertebral body of L7 instead. Given the loss of normal anatomic landmarks, we speculate that, in this case, an open approach without fluoroscopic guidance would have presented a significant challenge.

Screw sizes described for SIL stabilization in cats range from 1.5 to 4.0 mm, but the screw sizes used most frequently are 2.4 and 2.7 mm.[7,16,19] In our study, 19/20 were 2.4 mm screws and 1/20 was a 2.7 mm screw. Our drill guide system is designed for 2.4 mm screw placement and, therefore, the placement of a 2.7 mm diameter screw required manual over drilling. To continue improving the system additional drill guides for larger screws might be developed. One previous study found that the use of 2.7 mm screws significantly decreased the possibility of implant loosening in cats.[7] Nevertheless in that study, 2.7 mm screws were compared only against 1.5, 2.0, 3.5 and 4.0 mm screws and not against 2.4 mm screws. To the best of the authors knowledge, the are no studies showing superior outcome when using 2.7 mm screws instead of 2.4 mm screws for sacroiliac stabilization in cats. Consequently, guidelines are not available, and implant selection remains at the discretion of the surgeon. Further studies to evaluate the impact of screw diameter on outcome are required to more appropriately guide the clinician in decision making.

The limitations associated with this study are largely related to its retrospective nature which introduced inconsistencies with the available pre- and postoperative imaging modalities (i.e., CT scan vs. radiographs) and availability of data such as anesthetic and surgical times. A prospective study design, with a set imaging modality would address this limitation. Finally, a larger population size might have allowed identification of intraoperative complications that did not occur in our study.

The aim of this report was to describe the surgical technique, its accuracy and the difficulties associated with its execution. For this reason, clinical outcomes were not evaluated. Cats that suffer SIL, commonly have concomitant injuries due to the force of the trauma needed to cause the SIL in first instance. Consequently, trying to assess outcome associated with different surgical techniques in these patients is extremely challenging. This is why most studies on SIL treatment, including the present study, focus on alternative outcome measures including sacroiliac reduction, screw location/orientation and sacral purchase rather than on functional outcome.

## 5 | CONCLUSION

Stabilization of SIL in cats by means of a single iliosacral screw placed minimally invasively using intraoperative fluoroscopy and a table bound reduction system and 3D printed drill guide system led to screws that were placed accurately within the sacral body.

### AUTHOR CONTRIBUTIONS

López Barroso Y, DVM, MRCVS: Data collection and analysis, drafting the manuscript, selecting images and research of the subject. Final approval of the version to be published. Agreement to be accountable for all aspects of the work. Anesi S, DVM, MVM, DECVS, MRCVS: Significant contribution to the study design, acquiring, analyzing and interpretation of data for the work including radiographs and computed tomography measurements. Reviewing the manuscript both grammatically and intellectually. Final approval of the version to be published. Agreement to be accountable for all aspects of the work. Clarke S, BVM&S, DSAS (Orth), DECVS, MRCVS: Significant contribution to the conception of the work. Reviewing the manuscript both grammatically and intellectually. One of the two board-certified surgeons who performed the technique described in the manuscript. Final approval of the version to be published. Agreement to be accountable for all aspects of the work. Bilmont A, DVM, DECVS, MRCVS: Significant contribution to the conception of the work. Reviewing the manuscript both grammatically and intellectually. One of the two board-certified surgeons who performed the technique described in the manuscript. Final approval of the version to be published. Agreement to be accountable for all aspects of the work.

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### CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this report.

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