Received: 28 January 2024 | Revised: 24 August 2024 | Accepted: 4 September 2024
DOI: 10.1111/vsu.14167

CLINICAL RESEARCH

WILEY

Stabilization of 82 sacroiliac luxations in 67 cats using two sacroiliac screws (2014–2023)

Kevin R. L. Schreiber DVM | Alexandre Thibault DVM | Martin Hamon DVM, DECVS | Philippe Haudiquet DVM, DESV, DECVS

VetRef – AniCura, Beaucouze, France

Correspondence
Kevin R. L. Schreiber; 7 rue James Watt
49070 Beaucouze France.
Email: k.schreiber1@outlook.fr

Abstract

Objective: To describe sacroiliac luxation stabilization in cats using two screws and to report clinical and radiographic short-term outcomes.

Study design: Retrospective clinical cohort study.

Sample population: Cats ($n = 67$) with sacroiliac luxation.

Methods: Case records of cats presented for sacroiliac luxation stabilized using two screws per side affected, one lag and one positional, between 2014 and 2023 were reviewed. The percentage of sacral purchase (PoSP) for each screw, percentage of reduction (PoR), and pelvic canal width ratio (PCWR) were measured and calculated.

Results: Eighty-two sacroiliac luxations were stabilized. Two 2.0 mm screws were used in 69 cases; two 2.4-mm screws in nine cases, and one 2.4 mm with one 2.0 mm screw in four cases. The mean PoSPs for lag and positional screws were 46% ± 12 and 31% ± 11, respectively. The median PoR was 89% (41 to 100). The mean PCWR was 1.23 ± 0.11. Clinical follow up was available for 42 cats with 53 sacroiliac luxations at a median of 87 days (36 to 2503). The full function was noted in 34 patients (81%). Screw failure occurred in five sacroiliac joints (4.7%), including loosening ($n = 3$), and breakage ($n = 2$) of the positional screws ($n = 1$). Pelvic canal diameter was maintained in all cases.

Conclusion: Excellent functional and radiographic outcomes were obtained for cats with sacroiliac luxation stabilized with two sacroiliac screws.

Clinical significance: Feline sacroiliac luxation can be stabilized using two sacroiliac screws.

1 | INTRODUCTION

Sacroiliac luxation (SIL) is commonly reported in cats following a trauma or a drop.[1] It was the most common pelvic bone injury, reported in up to 59% of cases.[2] In unilateral presentation, the luxation was accompanied by one or more pelvic injuries, most often involving the pubis, the ischium, or the contralateral ilium.[2] Bilateral luxations without concurrent pelvic injuries were reported in 18% to 46% of cases.[2–4]

A surgical treatment is often recommended for stabilizing SIL in dogs and cats.[2,5,6] Conservative management may be considered in selected cases, such as ambulatory patients with less than 50% displacement of

Abbreviations: CT, computed tomography; ICC, intraclass coefficient correlation; IO, internal osteosynthesis; PCWR, pelvic canal width ratio; PCWRimm, PCWR obtained immediately after the surgery; PCWRout, PCWR obtained during the follow up; PoR, percentage of reduction; PoSP, percentage of sacral purchase; Q1, first quartile; Q3, third quartile; ROM, range of motion; SIL, sacroiliac luxation.

the iliac wing, minimal pain or instability, no fractures involving the weight-bearing axis, no neurological deficits, and no substantial pelvic canal narrowing.[2,6,7] Several methods for stabilizing SIL have been described, including a single lag fashion screw,[8–10] a single transsacroiliac pin,[11] or a single transsacral screw and nut,[12] transiliac techniques,[13] a tension band technique,[14] ventral screw placement,[15] transsacroiliac toggle suture repair,[16,17] and single sacroiliac cannulated compression screw.[18] A single lag fashion screw is most often used to stabilize SIL in cats.[8–10,12] A sacral purchase of at least 60% and the largest possible diameter of screw placement are recommended to limit postoperative complications,[19,20] which include screw loosening and narrowing of the pelvic canal diameter.[20] Anatomic landmarks on the iliac wing and sacral body and screw angulation have been determined to define a safe sacral corridor for screw placement in cats.[9,21] This safe corridor is limited, often with less than 0.5 cm^2 area reported in cats,[21] and the optimal screw purchase can be challenging to obtain. Accuracy in screw placement and sacral purchase are better obtained using fluoroscopic guidance,[4] but this technique is not available for all veterinary institutions.

A 1984 study demonstrated that a construct using two screws with a smaller diameter was stronger and stiffer than another using a single larger screw for stabilization of the SIL in a canine static ex vivo model.[19] More recently, in a static load-displacement ex vivo canine model, it was also shown that a construct using two shorter screws of 3.5 mm was stronger and stiffer than another using a longer screw with a diameter of 3.5 mm.[22] No mechanical advantage was observed between screws inserted in positional versus lag fashion.[22]

As far as the authors are aware, no published reports have described the use of two screws as a method of fixation for the stabilization of SIL in cats, either in cadaveric or clinical studies.

The objective of this study was to report radiographic and clinical short-term outcomes of SIL in cats stabilized with a technique using two sacroiliac screws. It was hypothesized that this technique would be effective in obtaining accurate screw purchase within the sacral body without downsizing the screw's diameter. It was also hypothesized that this technique would provide good short-term functional outcomes in cats.

2 | MATERIALS AND METHODS

2.1 | Study subjects

The medical records of cats that underwent SIL repair at a single referral center from January 2014 to July 2023 were reviewed. Cats that underwent the two-screw technique for stabilizing SIL were included in the study. Cats were excluded if another technique for SIL stabilization was used or if immediate postoperative radiographs following stabilization with the two-screw technique were unavailable. Data collected from medical records included signalment (breed, neuter status, age, weight), preoperative examination findings (clinical presentation, side luxation, concurrent injury), surgical findings (size of implants, reduction quality, and concurrent surgical procedure), radiographic measurements (reduction quality, percentage of sacral screw purchase, and pelvic canal diameter), and outcomes (date of follow up, clinical findings, radiographic findings, and complications).

Cats were classified according to the presence of bilateral (B) or unilateral (U) SIL and the presence of concurrent pelvic fracture affecting the weigh-bearing axis (iliac, acetabular, or sacral fracture) (Fx) or not (NFx).

2.2 | Surgical procedure

All procedures were performed under general anesthesia. Premedication was performed with diazepam (0.25 mg/kg IV) combined with morphine (0.2 mg/kg IV). Induction was obtained using ketamine (5 mg/kg IV; Ketamidor, Axience SAS, Pantin, France) and alfaxalone (2 mg/kg IV, titrated to effect; Alfaxan MD, Dechra Veterinary Product SAS, Montigny-le-Bretonneux, France). An endotracheal tube was placed, and general anesthesia was maintained with isoflurane (Isorane, Axience SAS, Pantin, France) in dioxygen. Intraoperative analgesia was obtained using a constant rate infusion of morphine 0.2 mg/kg/h and meloxicam (0.2 mg/kg SC; Metacam, Boehringer Ingelheim, Lyon, France). Each patient received surgical antibiotic prophylaxis with an injection of cefazolin (22 mg/kg IV) at induction.

Cats were aseptically prepared and placed in sternal recumbency with the pelvis raised over a sandbag and the pelvic limbs slightly abducted. The sacroiliac joint was accessed via a standard dorsal approach. Two surgical approaches were performed for bilateral SIL, one over each iliac wing. Bone-holding forceps with serrated jaws were placed on the cranial dorsal iliac spine to mobilize the iliac wing. The reduction was evaluated by palpation of the caudodorsal part of the sacroiliac joint (Figure 1). The reduction was considered optimal when the caudal dorsal iliac spine was located between the first intermediate sacral crest and the first lateral sacral crest (Figure 2). The reduction was maintained using pointed bone-holding forceps, applied between the iliac wing and the sacral crest. For the first drill, an anatomic landmark was determined by the intersection of a vertical straight line from the first sacral spine and a second straight line from the caudodorsal part of the sacroiliac joint with a cranioventral angulation of 45° to the horizontal (Figure 3). This landmark was similar to those previously described.[21] A 1.5 or 1.8 mm tunnel was then drilled through the iliac wing and the sacral body at the same time. Considering the feline anatomy of the sacral wing,[21,23] a ventral angulation of approximately 105 to 110° to the sagittal plane (15 to 20° to the dorsal plane) was maintained with the free-hand drill guide, and drilling continued through the sacral body (Figure 4). Low-speed drilling was performed until the ventral part of the sacral body was engaged to prevent iatrogenic damage to intrapelvic structures. If the ventral part of the sacral body was not crossed, the drilling was pursued as far as possible in the sacral body as described with the single lag screw technique.[6] The hole in the iliac wing was enlarged using a 2.0 or 2.4 mm drill bit. A self-tapping 2.0 or 2.4 mm screw of appropriate length was inserted in a lag fashion through the iliac wing and advanced into the sacral body. Pointed bone-holding forceps were removed to assess the compression and stability of the sacroiliac joint. A second 1.5 or 1.8 mm hole was drilled just caudally to the first one with the same orientation. A second self-tapping screw was placed in a positional fashion. The surgical wound was closed routinely.

FIGURE 1 Left dorsolateral view of a left sacroiliac luxation (SIL). A Hohmann retractor is positioned caudally to the sacral body, indicating the caudodorsal part of the sacroiliac joint. The C-shaped hyaline auricular cartilage of the sacral wing is visible (asterisk). Identifying these anatomical landmarks aids sacroiliac joint reduction.

Postoperative pain management was obtained with morphine (0.1 mg/kg IV) administered every 4 h until discharge. Meloxicam (0.05 mg/kg; Melosus, Axience SAS, Pantin, France) was administrated once a day postoperatively for 7 days.

FIGURE 2 Pelvic anatomy on dry bone in lateral (A) and dorsoventral (B) views. The caudodorsal part of the sacroiliac joint is marked by the red asterisk. The caudal dorsal iliac spine (arrow) is located between the first intermediate sacral crest (blue arrowhead) and the first lateral sacral crest (purple arrowhead.

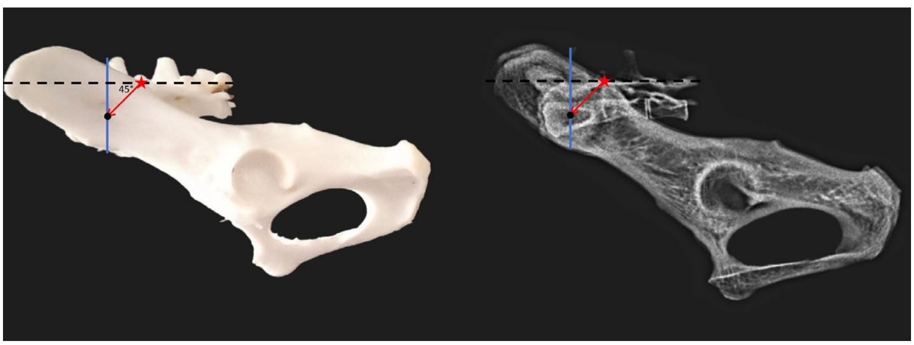

FIGURE 3 Pelvic anatomy on dry bone in lateral view (A) and radiographic projection (B). The ideal starting point for drilling the first screw is identified at the intersection of a vertical line (orange) from the first sacral spinal process and a 45° oblique line (red) relative to a horizontal line (blue) from the caudodorsal part of the sacroiliac joint.

Owners were instructed to keep their cats restricted at home without permitting jumping or access to stairs for 6 to 8 weeks postoperatively. This duration could vary depending on other orthopedic injuries that require longer restricted activity (e.g., acetabular fracture).

2.3 | Immediate postoperative radiographic evaluation

Postoperative standard ventrodorsal and lateral pelvis radiographs were performed to assess the position of the implants and bone reduction (Figure 4).

Several measurements were obtained on the ventrodorsal radiographic projection, as described previously[12,20] (Figure 5):

- Percentage of reduction (PoR) of sacroiliac joint: percentage of contact between joint surfaces.
- Percentage of sacral purchase of each screw (PoSP): percentage of the length of the screw anchored in the sacral body report on the width of the sacral body. The anchorage of each screw was referred to as the PoSP.
- Cumulative PoSP: addition of a PoSP of each screw (PoSP).
- Pelvic canal width ratio (PCWR): the ratio between pelvic width at the acetabulum's cranial aspect and the caudal sacrum's width. PCWR ≥1.1 was considered optimal, as described previously.[6,12,24]

2.4 | Immediate postoperative computed tomographic evaluation

A postoperative computed tomography (CT) scan was performed to evaluate the position of the implants in the sacral body, depending on the surgeon's experience and decision if any doubt in screw placement was present (Figure 6). The position of each screw within the sacral body was assessed using modifications of previously described grading for pedicle screws.[25] Sacral screws were classified as follows: Grade I referred to screws fully contained within the sacral body or exiting the ventral cortex by less than 2 mm (complete anchor

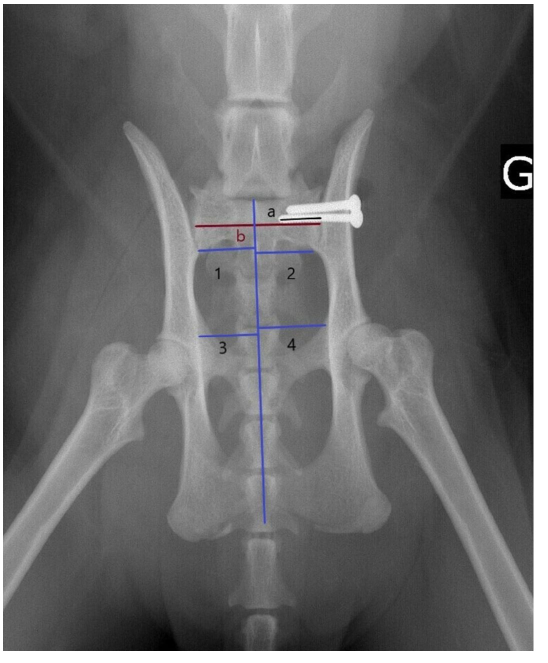

FIGURE 5 Postoperative ventrodorsal radiographic projection of the pelvis. The length of screw anchorage within the sacral body (A) and sacral body width (B) are measured to calculate percentage of sacral purchase (PoSP) ($a/b \times 100$). Pelvic canal width ratio (PCWR) is calculated ((3+4)/(1+2)): 1 and 2 are the perpendicular lines between the caudal aspect of each articular surface of the sacrum and the sagittal plane; 3 and 4 are the perpendicular lines between the cranial aspect of each acetabulum and the sagittal plane.

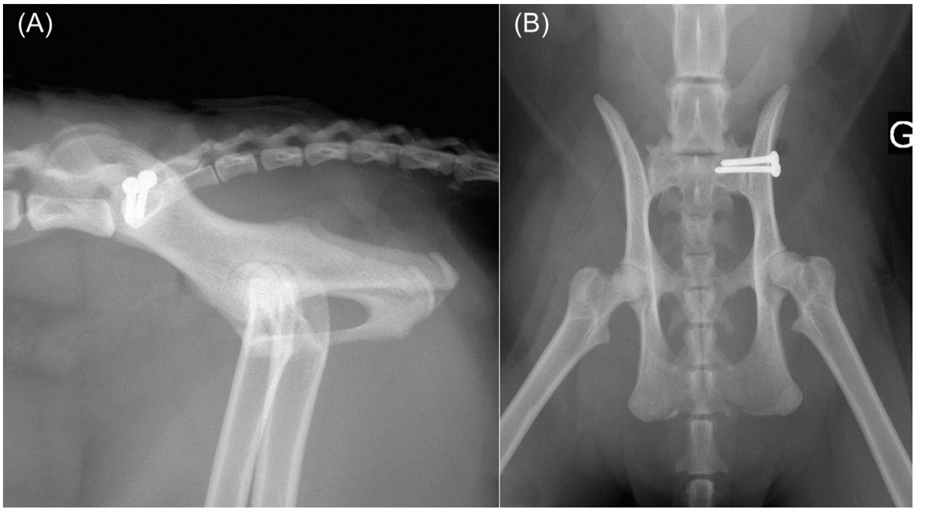

FIGURE 4 Postoperative lateral (A) and ventrodorsal (B) radiographic projections of the pelvis. Both screws are well positioned across the left ilium and sacral body. The reduction of the left sacroiliac joint is excellent. Note the ventral angulation of each screw in (A).

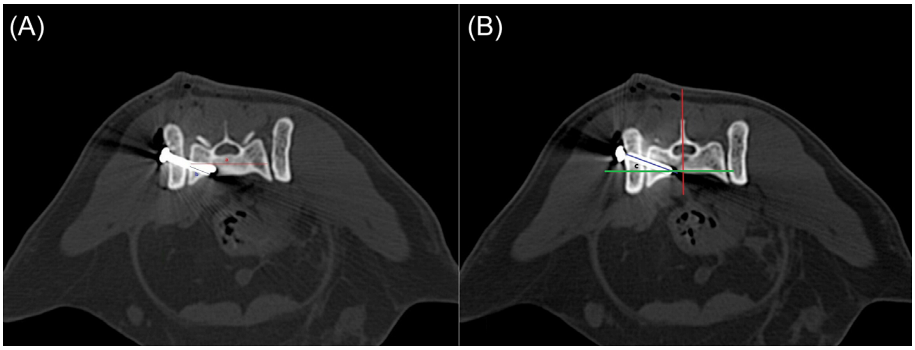

FIGURE 6 Postoperative transverse noncontrast computed tomography (bone window) images at the level of the lag screw (A) and positional screw (B) in a cat with right sacroiliac luxation (SIL). Sacral body width (A) and length of screw anchorage within the sacral body (B) are measured to calculate percentage of sacral purchase (PoSP) ($b/a \times 100$). The dorsoventral screw angle (C) is measured by the angle formed between the screw (blue line) and the dorsal axis (green line), with the dorsal axis determined by a right-angled line (green line) from the sagittal plane (red line).

through the trans cortex);[26] Grade IIa denotes screws slightly displaced dorsally with vertebral canal penetration less than 50% of the screw diameter; Grade IIb describes screws exiting more than 2 mm from the ventral cortex; and Grade III refers to screws penetrating the vertebral canal by more than 50% of the screw diameter. Screw placement was considered excellent when classified as grade I. The trajectory and anchorage of each screw were also measured and calculated (Figure 6):

The dorsoventral screw angle reffered to the angle between the screw and the dorsal plane axis in the transverse plane. A positive angle indicates the ventral deviation of the tip of the screw from the dorsal plane axis. Conversely, a negative value indicates a deviation in a dorsal direction.

The percentage of sacral purchase of each screw (PoSP) was measured and calculated as previously described.

2.5 | Follow up and outcome

Clinical examination and radiographic rechecks were scheduled for 8 weeks, 6 months, and 1 year postoperatively. The follow up was defined as perioperative (0 to 3 months), short term (3 to 6 months), mid term (6 to 12 months), and long term (>12 months). Clinical and radiographic outcomes and complications were recorded. A clinical score was used, adding the score of each of the following specific locomotor parameters: weight bearing at rest (1 normal; 2 slight easing of weight; 3 significant easing of weight; 4 complete non-weight-bearing), degree of lameness (1 none; 2 slight; 3 moderate; 4 severe), pain on palpation (1 none; 2 inducible by full extension/flexion of the hip; 3 inducible by minimal manipulation; 4 extreme reaction on palpation), and local inflammation (1 none; 2 slight; 3 moderate; 4 severe), as previously described.[27] Functional outcomes were classified as excellent (clinical score of 4), acceptable (clinical score between 5 and 10, with $\leq$3 in all categories), or unacceptable (clinical score greater than 10, or a score of 4 in any one category), according to the classification system described by Cook et al.[28] Postoperative complications were defined as catastrophic, major, or minor, as described in the literature.[28]

The patient was classed in the subgroup *r* when an implant failure was observed. Implant failure requiring surgical revision was classified as a major complication.

2.6 | Statistical analysis

Descriptive statistics were reported for each variable. For normally distributed data, means ± SD were used. For data that were not normally distributed, the median, interquartile range, first quartile, defined as the limit of the inferior quarter of the data arranged in ascending order (Q1), and third quartile, defined as the limit of the superior quarter (Q3) were used. Normality was assessed using a Shapiro–Wilk test. The PoR and PoSP for each screw, and the PCWR obtained immediately after the surgery ($PCWR_{imm}$) and during the follow up ($PCWR_{out}$) were compared between groups U and B, and Fx and NFx, respectively; $PCWR_{imm}$ and $PCWR_{out}$ were also compared for subgroup *r*. A Student test was used for data normally distributed, and a Mann–Whitney test was used for data not normally distributed. A paired-sample Student test was used to compare $PCWR_{imm}$ and $PCWR_{out}$ if the normality of data was obtained. A $p < .05$ was considered significant for analyses. All statistical analyses were performed using RStudio 2022.12.0 + 353 (Posit Software, PBC, Boston, Massachusetts, United States). The intraclass coefficient correlation (ICC) was calculated for PoSP of each screw measured on postoperative radiographs and CT scan using a two-way mixed effect, absolute agreement, single rater/measurement, as previously described.[29]

3 | RESULTS

3.1 | Study subjects

Sixty-seven cats were included in the study. Breed distribution was: 61 domestic shorthair cats and one cat of each following breeds (Maine coon, Norwegian forest cat, Birman, Siamese, Persian, Ragdoll). Thirty-four cats were males, and 33 were females. The median age was 35 months (range, 7 to 141). The median body weight was 4.0 kg (range, 2.3 to 8.8). All cats were non ambulatory on the pelvic limbs at presentation but retained sensation and motor function, except for one cat, which had lost the deep pain sensation of the ipsilateral hindlimb. Proprioception on the pelvic limbs ($n = 56$) was present in 37, absent in nine on the ipsilateral side of the SIL, and absent in 10 cats on the contralateral side of the SIL. Voluntary micturition ($n = 67$) was present in 58 cats, and absent in nine with sacrocaudal fracture/luxation ($n = 7$), abdominal hernia with bladder herniation ($n = 1$), and unilateral SIL with a contralateral iliac fracture ($n = 1$).

Eighty-two SILs were reported in the 67 cats, with 27 affecting the right side, 25 on the left side, and 15 involving both sides. Sixty-six cats had a concurrent injury, with 52 having two or more, making a total of 146 concomitant injuries. Twenty-six cats were included in the group Fx and 41 in the group NFx. The majority of the injuries involved the pelvis ($n = 127$): 41 pubic fractures, 36 ischial fractures, 18 iliac fractures, 11 pubic symphysis disjunctions, nine sacrocaudal fractures/luxations, seven acetabular fractures, and six sacral fractures (five type I including sacroiliac fracture/luxation and one type II). Other orthopedic injuries ($n = 14$) included six femoral fractures, two mandibular symphysis disjunctions, two hip luxations, one tibial fracture, one tarsocrural joint luxation, one metatarsal fracture, and one occipital fracture. Nonorthopedic injuries ($n = 4$) included two diaphragmatic hernias, one inguinal hernia, and one bladder rupture.

3.2 | Surgical procedure

Eighty-two SILs were stabilized with two screws. Two screws of 2.0 mm were used to stabilize 69 SILs, two 2.4 mm screws were used for nine SILs, and 2.4 mm lag with 2.0 mm positional screws were used in four SILs.

Concurrent procedures were performed in 43 cats, including 38 orthopedic and 13 nonorthopedic procedures. Orthopedic stabilizations included: 16 iliac internal osteosynthesis (IO), six femoral IO, six acetabular IO, three sacral IO, two symphysis mandibular stabilizations, two head and neck femoral excisions, one tibial IO, one tarsocrural stabilization, and one metatarsal IO. Nonorthopedic procedures included: seven tail amputations, three herniorrhaphies (one inguinal and two diaphragmatic), two sacrocaudal alignments with sutures or cerclage wire, and one bladder repair.

All cats, except the one with an absent deep pain sensor, were ambulatory before the hospital discharge. Proprioception was present in 47 cats and absent in 19 cats (preoperatively absent). Voluntary micturition was present in 65 cats and absent in two cats (preoperatively absent).

3.3 | Immediate postoperative radiographic evaluation

Immediate postoperative radiographs were obtained for all cats.

The mean radiographic PoSP was 46 ± 12% and 31 ± 11% for lag fashion and positional screws, respectively. The mean radiographic PoSP of lag and positional screws were 47 ± 12% and 31 ± 11%, 46 ± 12% and 32 ± 12%, 45 ± 12% and 30 ± 11%, and 47 ± 12% and 32 ± 11% for groups B, U, Fx, and NFx, respectively. The mean cumulative PoSP was 77 ± 21% for all cats, and 78 ± 21%, 78 ± 20%, 74 ± 21%, and 78 ± 21% for groups B, U, Fx, and NFx, respectively. The minimum cumulative radiographic PoSP was 20% associating 11% for the lag screw and 9% for the positional screw.

The median immediate postoperative PoR was 89% (41 to 100; Q1: 75; Q3: 100) for all cats, and 84% (41 to 100; Q1: 71; Q3: 95), 93% (47 to 100; Q1: 78; Q3: 100), 96% (41 to 100; Q1: 73; Q3: 100), and 87% (range, 52 to 100; Q1: 78; Q3: 100) for groups B, U, Fx, and NFx, respectively. The mean $PCWR_{imm}$ was 1.23 ± 0.11 for all cats. The mean $PCWR_{imm}$ was 1.25 ± 0.09, 1.23 ± 0.12, 1.19 ± 0.12 for group Fx, and 1.26 ± 0.10 for groups B, U, Fx, and NFx, respectively.

3.4 | Immediate postoperative computed tomographic evaluation

Immediate postoperative CT scan was performed in 27 cats with 33 SILs leading to 66 screw assessments. One grade IIa complication was observed. The screw was immediately removed, and another screw with optimal length was positioned. For the 65 other screws (98.5%), the placement within the sacral body was considered excellent (grade I). The ventral cortical of the sacral body was penetrated for 45 screws (20 lag and 25 positional screws) (68%).

The mean computed tomographic PoSP was 50 ± 11% and 31 ± 12% for lag fashion and positional screw, respectively. The mean cumulative PoSP was 81 ± 18%. The minimum cumulative PoSP was 38% associating 21% for the lag screw and 17% for the positional screw. An excellent agreement between radiographic and computed tomographic PoSP was obtained with an ICC of 0.937 and a 95% confidence interval ranging from 0.898 to 0.961.

The median dorsoventral screw angle was 22° (−3.2 to 41; Q1: 19; Q3: 27) for the lag screw and 23° (0 to 42; Q1: 20; Q3: 32) for the positional screw.

3.5 | Follow up and outcome

Follow up was available in 43 cats with a median of 87 days (30 to 2503), including 17 cats with an immediate postoperative CT scan evaluation at a median of 69 days (30 to 1008). One cat with a unilateral SIL was excluded from the clinical follow up because of pelvic limb amputation for the absence of deep pain sensation.

Thirty-two cats (39 SILs), 13 cats (17 SILs), and nine cats (11 SILs) were reviewed during the perioperative, short- and medium- to long-term (median, 361 days) periods, respectively. Seven cats from mid- to long-term follow up were reevaluated during the perioperative ($n = 5$) or the short-term ($n = 2$) periods. Radiographic examination was available in 41 cats (51 SILs) at a median of 87 days, including 16 cats with an immediate postoperative CT scan evaluation. The mean $PCWR_{out}$ was 1.21 ± 0.11 for all cats, 1.22 ± 0.12 for cats with an immediate postoperative CT scan evaluation, and 1.20 ± 0.10 for cats with only an immediate postoperative radiographic evaluation. Breakage ($n = 2$) and loosening ($n = 3$) of one positional screw were reported in five different cats, including four with bilateral and one with a unilateral SIL ($PCWR_{imm}$: 1.15, 1.32, 1.24 and 1.19; $PCWR_{out}$: 1.15, 1.32, 1.33 and 1.18, respectively). Due to insufficient radiographic quality, PCWR was not measured in the cat with a unilateral SIL. Implant failure for the stabilization of iliac ($n = 1$), acetabular ($n = 1$), and sacral ($n = 1$) fractures were observed in three different cats ($PCWR_{imm}$: 1.07, 1.05, and 1.1; $PCWR_{out}$: 1.07, 1.03 and 1.02, respectively).

Clinical complications occurred in five cats, including four minor (persistent tail paresis, contralateral sciatic nerve paresis at short-term resolved at mid-term periods, obstipation, and persistent urinary incontinence) and one major complication (obstipation). Four of these were related to a concurrent injury: sacrocaudal luxation (tail paresis and urinary incontinence), long oblique medially displaced iliac with sacral fractures (sciatic nerve paresis), and sacral fracture (obstipation).

The median clinical score ($n = 42$) was 4 (range 4 to 7; Q1: 4; Q3: 4). The functional outcome was considered excellent in 34 cats (81%) and acceptable in eight (19%) cats with slight to moderate lameness on the ipsilateral ($n = 5$) or the contralateral ($n = 3$) side of SIL. Cats with persistent functional abnormality also had concurrent fractures in 7/8 cases. The median clinical score for cats with an immediate postoperative CT scan ($n = 17$) was 4 (range 4 to 7; Q1: 4; Q3: 4). The functional outcome was considered excellent in 14 (82%) and acceptable in 3 (18%) cats. The median clinical score for cats having only an immediate postoperative radiographic evaluation ($n = 25$) was 4 (range, 4 to 7; Q1: 4; Q3: 4). The functional outcome was considered excellent in 20 (80%) and acceptable in five (20%) cats. Twenty-three had a PoR below 90% with an excellent (18/23) or acceptable (5/23) functional outcome reported. Nine had an immediate postoperative cumulative PoSP of less than 60% measured on radiographs (median: 52; range: 47 to 59), with an excellent (6/9) or acceptable (3/9) functional outcome reported. Two had an immediate postoperative cumulative PoSP of less than 60% measured on CT scan (38% and 59%, respectively), with an excellent (2/2) functional outcome reported.

3.6 | Statistical analysis

The pelvic canal diameter was maintained for all cats ($PCWR_{imm}$: 1.23 ± 0.12; $PCWR_{out}$: 1.21 ± 0.11; $p = .121$; paired t-test), for cats with an immediate postoperative CT scan ($PCWR_{imm}$: 1.25 ± 0.13; $PCWR_{out}$: 1.23 ± 0.11; $p = .191$; paired t-test), and for cats with only an immediate postoperative radiographic examination ($PCWR_{imm}$: 1.21 ± 0.11; $PCWR_{out}$: 1.20 ± 0.10; $p = .31$; paired t-test), even for subgroup r ($PCWR_{imm}$: 1.2 ± 0.13; $PCWR_{out}$: 1.16 ± 0.11; $p = .110$; paired t-test).

Performing an immediate postoperative CT scan evaluation did not affect the functional outcome ($p = .773$, Mann–Whitney test) or the $PCWR_{out}$ ($p = .636$, t-test).

Reduction of the sacroiliac joint did not impact the sacral purchase of lag ($p = .905$; t-test) or positional ($p = .507$; t-test) screws nor the functional outcome ($p = .656$; Mann–Whitney test).

The cumulative sacral purchase of each screw lesser than 60% did not impact the functional outcome

($p = .235$; Mann–Whitney test) nor the maintenance of the pelvic canal diameter over time ($PCWR_{imm}$: 1.18 ± 0.10; $PCWR_{out}$: 1.17 ± 0.13; $p = .326$; paired *t*-test).

Bilateral SILs ($n = 15$) did not impact the quality of the reduction ($p = .102$; Mann–Whitney test), the sacral purchase of lag ($p = .515$; *t*-test) and positional ($p = .800$; *t*-test) screws, and the $PCWR_{imm}$ ($p = .527$; *t*-test) in comparison with unilateral SILs ($n = 52$). The pelvic canal diameter was maintained ($PCWR_{imm}$: 1.22 ± 0.12; $PCWR_{out}$: 1.22 ± 0.10; $p = .500$; paired *t*-test) and slightly reduced ($PCWR_{imm}$: 1.25 ± 0.10; $PCWR_{out}$: 1.21 ± 0.12; $p = .008$; paired *t*-test) for cats from group U and B, respectively. The clinical follow up was available in 31 (U) and 11 (B) cats. Lateralization of the SIL did not impact the functional outcome (excellent: 25/31 (U) and 9/11 (B); acceptable: 6/31 (U) and 2/11 (B); $p = .764$; Mann–Whitney test).

Cats with a concurrent pelvic fracture involving the weight-bearing axis ($n = 26$) had a lower $PCWR_{imm}$ in comparison with other cats ($n = 41$) (1.19 ± 0.12 vs. 1.26 ± 0.10; $p = .005$; *t*-test). No impact of concurrent pelvic fracture on the quality of reduction ($p = .585$; Mann–Whitney test), the sacral purchase of lag ($p = .507$; *t*-test), and positional ($p = .550$; *t*-test) screws were observed. The pelvic canal diameter was reduced ($PCWR_{imm}$: 1.28 ± 0.10; $PCWR_{out}$: 1.24 ± 0.09; $p = .006$; paired *t*-test) and maintained ($PCWR_{imm}$: 1.17 ± 0.12; $PCWR_{out}$: 1.18 ± 0.12; $p = .284$; paired *t*-test) for cats from group NFx and Fx, respectively. The clinical follow up was available in 24 (NFx) and 18 (Fx) cats. Pelvic fracture involving the weight-bearing axis did not impact the functional outcome (excellent: 14/18 (Fx) and 20/24 (NFx); acceptable: 4/18 (Fx) and 4/24 (NFx); $p = .635$; Mann–Whitney test).

4 | DISCUSSION

Eighty-two SILs in 67 cats were stabilized using two sacroiliac screws placed with a blind fashion technique. One screw was placed in lag fashion, and the other in positional fashion. An excellent functional outcome was obtained in 81% of the cats.

It has already been observed that, except in giant-breed dogs, space in the sacral body is insufficient for a second deeply set screw.[30] In the present study, the placement of two screws was possible in all cats. Only one vertebral canal penetration occurred on the 66 screws checked on postoperative CT scan ($n = 27$). Screw placement was considered excellent for the 65 other screws (98%). It was better than previously reported with minimally invasive techniques (84% to 92%).[31,32] However, in our study, a fully contained screw within the sacral body and exiting the ventral cortical less than 2 mm was considered excellent. In previous studies, screw placement was considered excellent if a sacral purchase of at least 60% preserving the vertebral canal was obtained. Several factors could explain the low rate of vertebral canal penetration observed in the present study. First, the reference point for positioning the lag screw was determined according to anatomic landmarks on the sacrum. As a result, the lag screw placement was about the sacrum and, therefore, about the vertebral canal, which will always be the same, irrespective of the quality of the reduction. Second, the ventral orientation of the screws directs them away from the vertebral canal. Finally, this technique uses small diameter screws, which could lead to less risk for penetration of the vertebral canal in this small safe area.[21,32]

Small diameter screws were used in comparison with those used in previous studies of single-screw technique,[10,12,15,23,32] including a large majority of 2.0 mm screws (142/164). A PoSP of at least 60% is recommended when a single lag fashion screw is used, to decrease the rate of loosening.[19,20] Hanlon et al.[22] reported that a PoSP of 23% applied with two cortical screws offered greater stiffness of stabilization than a PoSP of at least 60% applied with a single cortical lag screw in dogs. In our study, a mean anchorage of 46% ± 12 and 31% ± 11 were observed for lag fashion and positional screws, respectively. No impact of the percentage of anchorage of each screw was observed on the stability of the sacroiliac joint or the functional outcome when the cumulative PoSP was over 38%. However, no conclusion for our study's cumulative PoSP of less than 38% can be established. The better stability obtained with two shorter screws for SIL could be explained by the greater strength against torsional, bending, and shear forces,[19] despite an intrinsic greater stiffness for a larger screw than two screws of the same diameter (radius-dependent stiffness to the power of 4). Moreover, the ventral orientation applied on the screws in the present study leads to a complete purchase through the sacral body and across the ventral cortical bone (45/66). This results in an anchorage through a cis- and a trans cortical bone of the sacral body. The pullout strength of a bicortical screw is greater than a monocortical screw in a canine humeral ex vivo model.[33]

Rates of loosening between 0% and 53% following SIL stabilization were reported in previous studies.[3,4,8,12,15,18] Placement of a long lag fashion screw was more effective with fluoroscopic guidance.[4] In our study, five implant-related complications were observed during the radiographic re-examination, including the loosening of three positional screws and the breakage of two in one case for each ($n = 1$). The screw complications involved the positional screw in all cases. An explanation for this observation could be the greater stress supported by the positional screw in comparison with the lag screw. The lag screw acts as a pivot point for the sacroiliac joint, and the positional screw around this point counteracts a lot of bending and rotational forces. Range of motion (ROM) for the sacroiliac joint has not been evaluated in cats but it has been measured in dogs using several different methods ranging from radiographic studies of dissected pelves (median ROM, 7°) to tomographic studies of anesthetized purebred dogs (mean ROM, $2.0 \pm 1.5°$ for German shepherd dogs and $1.5 \pm 0.7°$ for greyhounds).[34,35] An increased ROM for the sacroiliac joint could be observed with a traumatic presentation, which could also increase the stress on each screw. Positional screw loosening or breakage was observed in four cats with bilateral SIL. Shearing, bending, and pull-out forces on the weight-bearing axis may be modified with bilateral SIL, particularly on the stabilized sacroiliac joints. In cats, limited bone stock is available in the caudo-ventral part of the sacral body. Considering this specific feline sacral anatomy, the holding strength of the caudal screw may be reduced.[21] Even if the positional screw underwent failure, the pelvic canal diameter was maintained over 1.1, as recommended.[24] Moreover, a weakness of the sacral body could be observed following the placement of two or four screws within it. However, no postoperative sacral body fracture was observed, even with the use of four screws up to 2.4 mm diameter.

Increased risk for loosening of fixation has been reported in dogs with a PoR lesser than 90% when a single lag screw was used.[20] In the current study, cats with a PoR below 90% had a similar rate of excellent functional outcomes (78%) as those with a PoR above 90% (84%; $p = .656$). Comparable results have been observed in previous studies using a single lag screw,[8] single transsacral screw and nuts,[12] tension band technique,[14] and cannulated screws.[31] The reduction was achieved by eyeballing sacral anatomic landmarks, which may decrease its accuracy without impacting the sacral purchase of each screw within the sacral body.

The functional outcome following SIL stabilization depends on the stability of the construct, its ability to maintain a physiological pelvic canal diameter, and the evolution of neurologic and concurrent injuries. In the current study, the pelvic canal diameter was maintained within recommended values[24] for all cats, even those with loosened fixation. These results were comparable with those obtained in previous studies using a single lag fashion screw.[11–13,24] In our study, eight cats presented an acceptable functional outcome related to persistent lameness during exercise, and/or reluctance to jump. For six of these eight cats, a concurrent injury was noted. This study reports the largest population of in cats with SIL stabilization, with results comparable to those reported in previous studies.[7,11–13,15]

The main limitation of this study is its retrospective nature over 10 years and its inherent lack of standardized follow up (only nine cats were reviewed after 6 months). The majority of cats had an excellent functional outcome at 8 weeks postoperatively, which could explain why so few cats were re-evaluated after 6 months. Medical records were not complete in all cats, particularly for neurologic findings, concurrent stabilization, screw diameter selection, or postoperative CT scan indication. Only 27 CT scans were performed postoperatively, which limits the interpretation of sacral screw placement and the accuracy of the outcomes. However, functional and radiographic outcomes were similar for cats with an immediate postoperative CT scan evaluation and cats with only radiographic evaluation in our study. The sacral ventral exit of the screw should reduce the accuracy of radiographic PoSP measurement. Our study did not verify this point regarding the ICC between radiographic and CT measurements. However, several factors could affect the accuracy of each measure, including the intraobserver and interobserver variability, the precision of the measurement technique, the angulation of the screw, the quality and the obliquity of the ventrodorsal radiographic projection, in addition to a Type II error phenomenon. Finally, functional outcome was scored using locomotor parameters. An approved owner questionnaire like a modified Feline Musculoskeletal Index[36] might have offered further details.

Stabilization of SIL in cats was possible using two sacroiliac screws by placing one in lag fashion and the other in positional fashion. A low rate of perioperative and postoperative complications was reported. This technique seems to be comparable in terms of functional recovery with previously published reports of other methods used to stabilize SIL in cats.

ACKNOWLEDGMENTS

Author Contributions: Schreiber K, DVM: Primary manuscript authorship, study design, assistance in surgical interventions, data gathering, data assessment, statistical analysis, drafting of the manuscript, manuscript figure design, revision of the manuscript, and approval of the final version of the submitted manuscript. Thibault A, DVM: Performance of surgical interventions, data gathering, data assessment, and manuscript review. Hamon M, DVM, DECVS: Performance of surgical interventions, data gathering, data assessment, manuscript review, and approval of the final version of the submitted manuscript. Philippe Haudiquet, DVM, DESV, DECVS: Project design, performance of surgical interventions, critical revision of the manuscript, and approval of the final version of the submitted manuscript.

The authors thank McGrotty Y, DVM, BVMS, cert. SAM, MRCVS, DECVIM-CA, for manuscript revision and approval of the final version by a native-speaking specialist veterinarian.

FUNDING INFORMATION

The authors received no funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ORCID

Alexandre Thibault https://orcid.org/0000-0001-9962-0223

REFERENCES

1. Lanz OI. Lumbosacral and pelvic injuries. *Vet Clin Small Anim Pract*. 2002;32(4):949-962. doi:10.1016/S0195-5616(02)00029-3
2. Bookbinder PF, Flanders JA. Characteristics of pelvic fracture in the cat. *Vet Comp Orthop Traumatol*. 1992;5(3):122-127. doi:10.1055/s-0038-1633081
3. Kaderly RE. Stabilization of bilateral sacroiliac fracture-Luxations in small animals with a single Transsacral screw. *Vet Surg*. 1991;20(5):281. doi:10.1111/j.1532-950X.1991.tb01266.x
4. Rollins A, Balfour R, Szabo D, Chesvick CM. Evaluation of fluoroscopic-guided closed reduction versus open reduction of sacroiliac fracture-Luxations stabilized with a lag screw. *Vet Comp Orthop Traumatol*. 2019;32(6):467-474. doi:10.1055/s-0039-1693471
5. Jacobson A, Schrader S. Peripheral nerve injury associated with fracture or fracture-dislocation of the pelvis in dogs and cats: 34 cases (1978-1982). *J Am Vet Med Assoc*. 1987;190(5):569-572.
6. Averill S, Johnson A, Schaeffer D. Risk factors associated with development of pelvic canal stenosis secondary to sacroiliac separation: 84 cases (1985-1995). *J Am Vet Med Assoc*. 1997;211(1):75-78.
7. Bird FG, de Vicente F. Conservative management of sacroiliac luxation fracture in cats: medium- to long-term functional outcome. *J Feline Med Surg*. 2020;22(6):575-581. doi:10.1177/1098612X19867516
8. Shales C, Moores A, Kulendra E, White C, Toscano M, Langley-Hobbs S. Stabilization of sacroiliac luxation in 40 cats using screws inserted in lag fashion. *Vet Surg*. 2010;39(6):696-700. doi:10.1111/j.1532-950x.2010.00699.x
9. Shales CJ, White L, Langley-Hobbs SJ. Sacroiliac luxation in the cat: defining a safe corridor in the dorsoventral plane for screw insertion in lag fashion. *Vet Surg*. 2009;38(3):343-348. doi:10.1111/j.1532-950X.2009.00509.x
10. Silveira F, Quinn RJ, Adrian AM, Owen MR, Bush MA. Evaluation of the use of intraoperative radiology for open placement of lag screws for the stabilization of sacroiliac luxation in cats. *Vet Comp Orthop Traumatol*. 2017;30(1):69-74. doi:10.3415/VCOT-15-12-0201
11. Parslow A, Simpson DJ. Bilateral sacroiliac luxation fixation using a single transiliosacral pin: surgical technique and clinical outcomes in eight cats. *J Small Anim Pract*. 2017;58(6):330-336. doi:10.1111/jsap.12659
12. Pratesi A, Grierson JM, Moores AP. Single Transsacral screw and nut stabilization of bilateral sacroiliac luxation in 20 cats. *Vet Comp Orthop Traumatol*. 2018;31(1):44-52. doi:10.3415/VCOT-17-03-0047
13. Yap FW, Dunn AL, Farrell M, Calvo I. Trans-iliac pin/-bolt/screw internal fixation for sacroiliac luxation or separation in cats: six cases. *J Feline Med Surg*. 2014;16(4):354-362. doi:10.1177/1098612X13503650
14. Raffan P, Joly C, Timm P, Miles J. A tension band technique for stabilization of sacroiliac separations in cats. *J Small Anim Pract*. 2002;43:255-260.
15. Borer LR, Voss K, Montavon PM. Ventral abdominal approach for screw fixation of sacroiliac luxation in clinically affected cats. *Am J Vet Res*. 2008;69(4):549-556.
16. Caron A. Feline bilateral sacroiliac luxation: medium-term outcome following surgical stabilization with Transsacral mini-tight rope in 9 cats. *Conference proceedings of the 21th ESVOT Congress*; 2022:100-101.
17. Froidefond B, Moinard M, Caron A. Outcomes for 15 cats with bilateral sacroiliac luxation treated with transiliosacral toggle suture repair. *Vet Surg*. 2023;52:983-993. doi:10.1111/vsu.14008
18. Jourdain M, Fernandes D, Védrine B, Gauthier PO. Fluoroscopically-assisted closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm headless cannulated compression screws: description, evaluation and clinical outcome. *Vet Surg*. 2024; 53(4):603-612. doi:10.1111/vsu.14070
19. Radasch RM, Merkley DF, Hoefle WD, Peterson J. Static strength evaluation of sacroiliac fracture-separation repairs. *Vet Surg*. 1990;19(2):155-161. doi:10.1111/j.1532-950X.1990.tb01158.x
20. DeCamp CE, Braden TD. Sacroiliac fracture-separation in the dog: a study of 92 cases. *Vet Surg*. 1985;14(2):127-130. doi:10.1111/j.1532-950X.1985.tb00841.x
21. Burger M, Forterre F, Brunnberg L. Surgical anatomy of the feline sacroiliac joint for lag screw fixation of sacroiliac fracture-luxation. *Vet Comp Orthop Traumatol*. 2004;17(3):146-151. doi:10.1055/s-0038-1632803
22. Hanlon J, Hudson CC, Litsky AS, Jones SC. Mechanical evaluation of canine sacroiliac joint stabilization using two short screws. *Vet Surg*. 2022;51(7):1061-1069. doi:10.1111/vsu.13857
23. Philp H, Durand A, De Vicente F. Use of computed tomography to define a sacral safe corridor for placement of 2.7 mm cortical screws in feline sacroiliac luxation. *J Feline Med Surg*. 2018;20(6):487-493. doi:10.1177/1098612X17716847
24. Tomlinson JL, Cook JL, Payne JT, Anderson CC, Johnson JC. Closed reduction and lag screw fixation of sacroiliac luxations and fractures. *Vet Surg*. 1999;28(3):188-193. doi:10.1053/jvet.1999.0188
25. Zdichavsky M, Blauth M, Knop C, Lotz J, Krettek C, Bastian L. Accuracy of pedicle screw placement in thoracic spine fractures - part II: a retrospective analysis of 278 pedicle screws

using computed tomographic scans. *Eur J Trauma*. 2004;30(4): 241-247. doi:10.1007/s00068-004-1423-8
26. Murphy TP, Hill CM, Kapatkin AS, Radin A, Shofer FS, Smith GK. Pullout properties of 3.5-mm AO/ASIF self-tapping and cortex screws in a uniform synthetic material and in canine bone. *Vet Surg*. 2001;30(3):253-260. doi:10.1053/jvet.2001.23344
27. Lascelles BDX, Henderson AJ, Hackett IJ. Evaluation of the clinical efficacy of meloxicam in cats with painful locomotor disorders. *J Small Anim Pract*. 2001;42(12):587-593. doi:10.1111/j.1748-5827.2001.tb06034.x
28. Cook JL, Evans R, Conzemius MG, et al. Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopedic studies in veterinary medicine. *Vet Surg*. 2010;39(8):905-908. doi:10.1111/j.1532-950X.2010.00763.x
29. Koo TK, Li MY. A guideline of selecting and reporting Intraclass correlation coefficients for reliability research. *J Chiropr Med*. 2016;15(2):155-163. doi:10.1016/j.jcm.2016.02.012
30. DeCamp CE, Braden TD. The surgical anatomy of the canine sacrum for lag screw fixation of the sacroiliac joint. *Vet Surg*. 1985;14(2):131-134. doi:10.1111/j.1532-950X.1985.tb00842.x
31. Fischer A, Binder E, Reif U, Biel M, Bokemeyer J, Kramer M. Closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm cannulated screws - a cadaveric study. *Vet Comp Orthop Traumatol*. 2012;25(1):22-27. doi:10.3415/VCOT-11-05-0074
32. Wills DJ, Neville-Towle J, Podadera J, Johnson KA. Computed tomographic evaluation of the accuracy of minimally invasive sacroiliac screw fixation in cats. *Vet Comp Orthop Traumatol*. 2022;35(2):119-127. doi:10.1055/s-0041-1736648
33. Vaughn DP, Syrcle JA, Ball JE, et al. Pullout strength of monocortical and bicortical screws in meta—physeal and diaphyseal regions of the canine humerus. *Vet Comp Orthop Traumatol*. 2016;29(6):466-474. doi:10.3415/VCOT-15-11-0192
34. Gregory G, Cullen J, Pool R. The canine sacroiliac joint: preliminary study of anatomy, histopathology, and biomechanics. *Spine (Phila Pa 1976)*. 1986;11:1044-1048.
35. Saunders FC, Cave NJ, Hartman KM, et al. Computed tomographic method for measurement of inclination angles and motion of the sacroiliac joints in German shepherd dogs and greyhounds. *Am J Vet Res*. 2013;74(9):1172-1182. doi:10.2460/ajvr.74.9.1172
36. Enomoto M, Lascelles BDX, Robertson JB, Gruen ME. Refinement of the feline musculoskeletal pain index (FMPI) and development of the short-form FMPI. *J Feline Med Surg*. 2022;24(2):142-151. doi:10.1177/1098612X211011984

How to cite this article: Schreiber KRL, Thibault A, Hamon M, Haudiquet P. Stabilization of 82 sacroiliac luxations in 67 cats using two sacroiliac screws (2014–2023). *Veterinary Surgery*. 2024;53(8):1366-1376. doi:10.1111/vsu.14167