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Evaluation of minimally invasive surgical reduction of sacroiliac luxation in toy breed dogs: a cadaver study

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ABSTRACT

Background: Minimally invasive surgery (MIS) technique of sacroiliac luxation in toy breed dogs using cannulated screws has not been described.
Objectives: The purpose of this study was to evaluate the effectiveness of pelvic canal recovery, the reproducibility of successful surgery outcomes, and the acceptable difficulty of the procedure in MIS of sacroiliac luxation in toy breed dogs.
Methods: MIS using 2.3-mm cannulated screws was demonstrated in 12 toy breed dog cadavers with sacroiliac luxation artificially induced. Pre and postoperative radiographs were used to evaluate the pelvic canal diameter ratio (PCDR), hemipelvic canal width ratio (HCWR), and reduction rate. Dorsoventral angle (DVA) and craniocaudal angle (CCA) of the inserted screw were obtained postoperative computed tomographic scan.
Results: The statistically significant difference between the mean pre and postoperative PCDR was found (1.10 ± 0.12 and 1.26 ± 0.11, respectively; $p = 0.002$), and the mean HCWR close to 1.0 meaning symmetric pelvis also was obtained (0.97 ± 0.07). The mean DVA and CCA were 2.26° ± 1.33° and 2.60° ± 1.86°, respectively.
Conclusions: MIS of sacroiliac luxation using 2.3-mm cannulated screws is applicable to toy breed dogs with acceptable difficulty.

Keywords: Minimally invasive surgery; sacroiliac joint; cadaver; dogs

INTRODUCTION

Sacroiliac luxation is common in dogs due to traumatic pelvic injuries, especially those caused by traffic accidents [1,2]. The surgical treatment of sacroiliac luxation is performed under extreme pain or severe displacement such as narrowing of the pelvic canal or misalignment of the coxofemoral joint, or to reduce the stress of surgical fixation conducted for a fracture of the pelvis or other long bones [3,4]. To date, various surgical techniques for sacroiliac luxation have been reported [5-10]. However, the surgical technique using a lag screw is a standardized surgical procedure that has been used widely [3,4], and the factors that contribute to the successful surgery have been reported as well [11].

The critical factor for successful surgery of sacroiliac luxation is to accurately insert the lag screws into the sacral body. This can prevent iatrogenic damage by reducing the possibility

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Conflict of Interest
The authors declare no conflicts of interest.

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of injuring the spinal cord, lumbosacral joint, peripheral vessels, or nerves, and can achieve stronger fixing force by making the screw threads more engaged in the sacral body [12].

In human medicine, a minimally invasive surgery (MIS) using fluoroscopy has been introduced for the surgical treatment of sacroiliac luxation, and is becoming the standard of sacroiliac luxation surgery. The advantages of this surgery include: (1) improved accuracy of screw insertion into the sacral body; (2) improvement of the sacral purchase of screw; (3) minimization of intraoperative hemorrhage; (4) reduction of the surgical time and hospitalization period; (5) fast weight bearing and pain reduction; and (6) low cost [13-16].

Studies on the successful application of MIS by using lag screws in dogs with sacroiliac luxation have been conducted in veterinary medicine as well [17,18]. Recently, it was shown that this technique enables a more accurate insertion of screws compared to the open reduction and internal fixation (ORIF) [19]. However, in all the three studies, this procedure was primarily performed on medium- and large-sized dogs. It seems that some toy breed dogs were included among the participants, but there is no information about the exact number; judging from the mean weight and weight range, they must have been a very small number. Furthermore, because the specific sizes of the surgical instruments and screws used in the toy breed dogs were not mentioned, it is difficult for clinicians to draw evidence about whether similar results as in the previous studies could be obtained by applying the MIS of sacroiliac luxation to toy breed dogs.

The purpose of this study was to describe the minimally invasive surgical reduction method by using 2.3-mm cannulated screws for toy breed cadaver dogs in which sacroiliac luxation was induced and to evaluate the effectiveness of this surgical technique. Hypothesis of this study was that this method has a significant pelvic canal widening effect and accuracy of screw placement into the sacral body which are acceptable to toy breed dogs.

MATERIALS AND METHODS

Cadaveric sacroiliac luxation model preparation

Twelve dog cadavers (mean weight: 3.66 ± 1.28 kg, range: 1.55 to 5.40 kg) euthanatized for reasons unrelated to this study and with no abnormalities in the sacroiliac joint and pelvis were used. Cadavers frozen at −17°C were thawed at room temperature 48 h before the surgical procedure. The pubis and ischium of one side were exposed through the ventral median approach and transected with bone cutter from the cranial and caudal sides of the obturator foramen. Subsequently, the ventral side of the sacrum was approached through an abdominal section, the sacroiliac joint capsule of the same side as the cutting side of pubis and ischium was incised, and the sacroiliac joint was dislocated manually. After the mobility of the dislocated hemipelvis was confirmed, closure was performed routinely.

Preoperative radiographic examination

A ventrodorsal radiograph of the cadaver pelvis was performed before surgery to confirm the proper execution of sacroiliac luxation and the absence of abnormalities in the transverse process of the 6th lumbar (L6) and 7th lumbar (L7) vertebrae to be used as a key landmark during surgery (**Fig. 1**). In this radiograph, the width of the sacrum at the level of 1st sacral body and the thickness of the iliac wing opposite to the luxation side were measured to determine proper length of the cannulated screws to be used in the surgery (between two

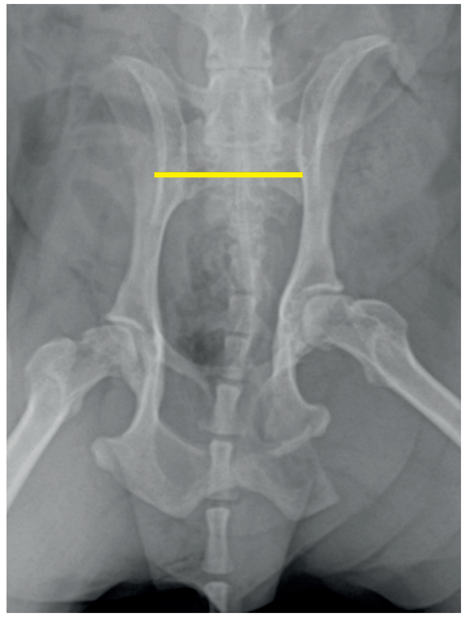

Fig. 1. Preoperative ventrodorsal radiographic view of cadaver pelvis of which sacroiliac luxation has been artificially induced. Pelvic canal narrowing due to sacroiliac luxation is observed. The length of the screw used for surgery is calculated from the sum of the sacral width and the width of one iliac wing (yellow line).

third and full of the measured length), and this radiograph was used to determine the preoperative pelvic canal diameter ratio (PCDR), which had been used as an indicator of the pelvic canal width in previous studies [17,18,20].

Surgical technique

After clipping, the cadaver was placed on the radiolucent operating table in lateral recumbency so that the surgical site would face upward. First of all, the fluoroscopic beam angle was adjusted under fluoroscopic guidance (KMC 650; Gemss Medical, Korea) to a point where the transverse processes of the L6 and L7 vertebrae are superimposed to align the fluoroscopic beam perpendicular to the sagittal plane of the sacrum. After confirming the location of the ischial tuberosity by palpation, a skin incision was performed immediately above it, and the ischial tuberosity was held with a towel clamp so that the hemipelvis of the sacroiliac luxation side could be moved. The towel clamp was pulled in the caudolateral direction under fluoroscopic guidance and stopped at a position where the iliac wings were superimposed (**Fig. 2**). The iliac wing of the dislocated side was held and lightly pushed down with the thumb and index finger so that the dislocated ilium and sacrum be in contact each other.

On the sacral body identified under fluoroscopic guidance, a stab incision was made on the skin and middle gluteal muscle parallel to the direction of the muscle fibers. The incision site was tunneled with mosquito hemostatic forceps to secure enough space for inserting a drill sleeve. A 0.8-mm guide wire (Guide Pin φ0.8mm; Jeil Medical Corporation, Korea) was inserted into the secured space to contact the iliac wing directly, and the tip was placed at the center of the sacral body on the fluoroscopic view. The 0.8-mm drill sleeve (Drill Guide φ0.8/1.8mm; Jeil Medical Corporation) was then inserted along the guide wire and directly touched the iliac wing, after which the guide wire was removed. In this condition, the exact vertical alignment of the drill sleeve was confirmed by the superimposition of the proximal and distal openings of the drill sleeve on the fluoroscopy. While taking care not to move the

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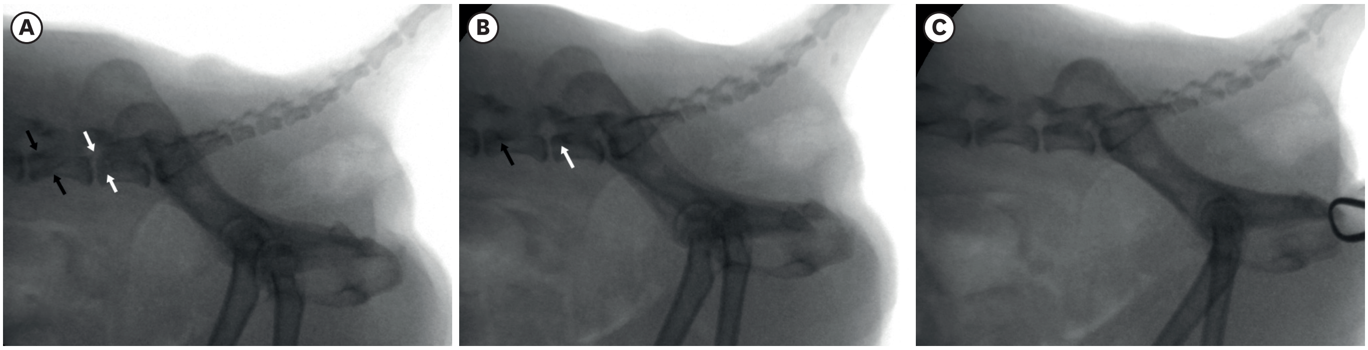

Fig. 2. Intraoperative lateral fluoroscopic views showing the procedures for alignment between fluoroscopic beam and sacrum and superimposition of iliac wings. (A) Superimposition of the transverse processes of the L6 (black arrows) and L7 (white arrows) is not accomplished. (B) The view after superimposition of the transverse processes L6 and L7. (C) Superimposition of the iliac wings is accomplished by caudolateral traction of the injuried hemipelvis using towel clamp.

drill sleeve, a 0.8-mm guide wire was inserted through the drill sleeve and the iliac wing into the sacral body (**Fig. 3**). A 1.8-mm cannulated drill bit (Cannulated Drill Bit φ1.8mm; Jeil Medical Corporation) was guided along the inserted guide wire and drilling was performed until the near and far cortexes of the iliac wing were perforated. A 2.3-mm partially threaded cannulated self-tapping cortical screw (Cannulated Screw Long Thread 2.3mm; Jeil Medical Corporation) of the proper length, which was determined in the preoperative radiograph, was prepared (**Fig. 4**) and guided along the guide wire until it was inserted into the sacral body.

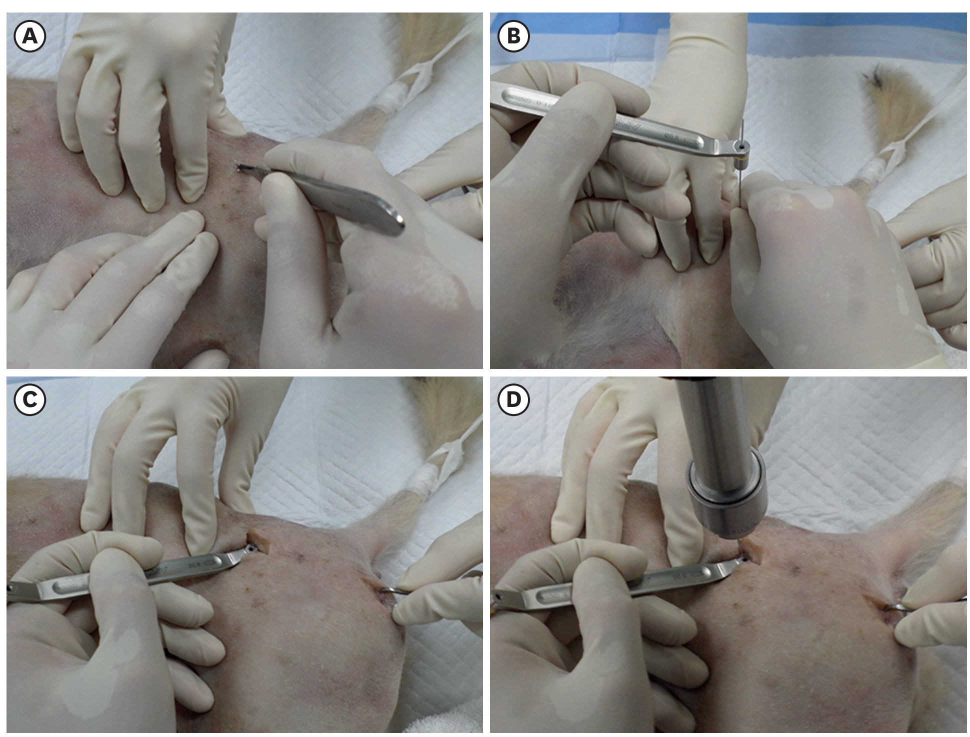

Fig. 3. Intraoperative images of minimally invasive surgery of toy breed dog cadaver with sacroiliac luxation. (A) After reduction of sacroiliac joint luxated, stab incision is made just above the site where the sacrum body is located on the fluoroscopic view. (B) After the tip of the guide wire on the fluoroscopic view is placed on the center of the sacral body, the 0.8-mm drill sleeve is inserted along the guide wire. (C) The exact alignment of the drill sleeve and the sacral body is tried by adjustment of the drill sleeve angle for the superimposition of the proximal and distal holes of the drill sleeve on the fluoroscopy. (D) Once the superimposition is confirmed, 0.8-mm guide wire is inserted through the drill sleeve into the sacral body.

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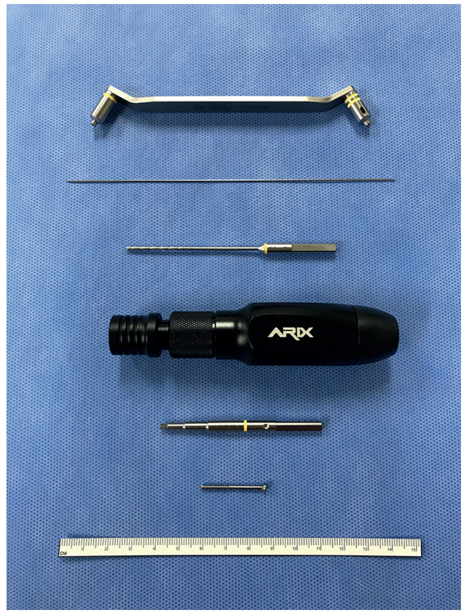

Fig. 4. The instrumentation of the 2.3-mm cannulated screw system used in this study. From top to bottom, 0.8-mm/1.8-mm double drill sleeve, 0.8-mm guide wire, 1.8-mm cannulated drill bit, handle for screwdriver with quick coupling, cannulated screwdriver shaft, and 2.3-mm partially threaded cannulated self-tapping cortical screw.

Subsequently, the fluoroscopic beam angle was adjusted on the dorsoventral view and the screw insertion was evaluated. After the proper insertion of the screw was confirmed, the guide wire was removed and the incised skin was sutured by the routine procedure. Every surgery was performed by one surgeon (SA). The lengths of the screws used in the surgery, surgical time (from the first skin incision over the ischial tuberosity to the last skin suture), fluoroscopic exposure time (FET), and technical difficulties and problems that happened during the surgeries were recorded.

Postoperative radiographic and computed tomographic (CT) examination

Ventrodorsal and laterolateral pelvic radiography and CT imaging of the cadavers were performed after surgery. The radiographs were used to determine the postoperative PCDR that was used to evaluate the relative increase in pelvic canal diameter in comparison with preoperative PCDR, the hemipelvic canal width ratio (HCWR) that was used to evaluate the symmetry of the pelvic canal in previous studies [17,18,20], and the sacroiliac reduction rate (RR). The CT results were used to examine the existence of abnormalities or damages in the sacral specimens that could occur during the process of creating a sacroiliac luxation model or conducting surgery. Furthermore, they were also used to observe any protrusions of the inserted screws into the lumbosacral joint, spinal canal, or pelvic canal beyond the sacral body. In addition, the dorsoventral angle (DVA) and the craniocaudal angle (CCA) which were used to evaluate the accuracy of screw insertion in previous studies [19], and the sacral body diameter (SBD) and width, were also measured.

Data processing

All the data obtained from this study were measured and calculated by one person (SA). For the preoperative and postoperative PCDRs, the width of the pelvic canal at the acetabulum level divided by the width of the sacrum on the ventrodorsal pelvis radiograph was calculated [21]. For the HCWR, a virtual central line connecting the spinous process of sacrum and the pubic symphysis was drawn on the ventrodorsal pelvis radiograph. Subsequently, the

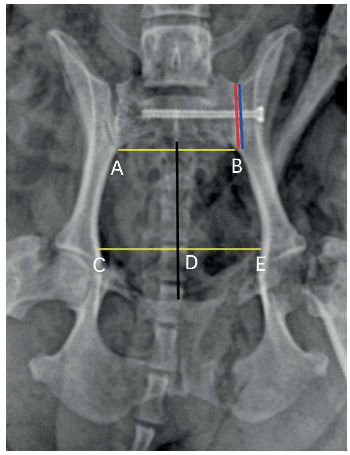

Fig. 5. Postoperative ventrodorsal pelvis radiographic view showing the measurement method for evaluating the pelvic canal recovery effect. Pelvic canal diameter ratio equals CE/AB. Hemipelvic canal width ratio equals DE/CD. RR equals blue line/red line (blue line: the craniocaudal length of iliac joint facet in contact with sacral articular surface, red line: the craniocaudal length of sacroiliac joint). The black line is drawn from the spinous process of the sacrum to the pelvic symphysis.

distance from the acetabulum level on each side to the central line was determined, and the distance of the operated side divided by the distance of the opposite side was obtained [17]. For the RR, the length of the part where the iliac joint facet contacted the sacral joint facet on the ventrodorsal pelvis radiograph was determined and expressed as a percentage of the sacroiliac joint length [11] (**Fig. 5**).

The raw data obtained from the CT scan was processed with an imaging software (OsiriX Imaging Software v.8.5.1; Pixmeo SARL, Switzerland) in the same way as in a previous study [19]. In OsiriX, all sacra were imaged on the transverse plane, sagittal plane, and dorsal plane through multiplanar reconstructions and were aligned with each plane in the following way to standardize the angle of screw deviation. On the transverse and dorsal plane views, the spinous processes of L7 and sacrum were aligned with the sagittal plane, and on the sagittal plane view, the floor of the spinal canal of the sacrum was rotated to be aligned in parallel with the dorsal plane (**Fig. 6**). After the alignment, the angle formed by the dorsal plane and the screw axis was measured on the transverse plane view to determine the DVA value, and the angle formed by the transverse plane and the screw axis on the dorsal plane view was measured to determine the CCA value. On the sagittal plane view, the largest circle that contacts the sacral body boundary was drawn and the diameter of this circle was measured to determine the SBD value (**Fig. 7**).

Statistical analysis

All the data were represented by the mean value, standard deviation, and range. The preoperative and postoperative PCDRs were compared through the Wilcoxon Signed Rank Test statistical analysis. All the data analyses were performed using SPSS version 24 (IBM Corporation, USA) for Mac (Apple Inc., USA). The statistical significance was set at $p < 0.05$.

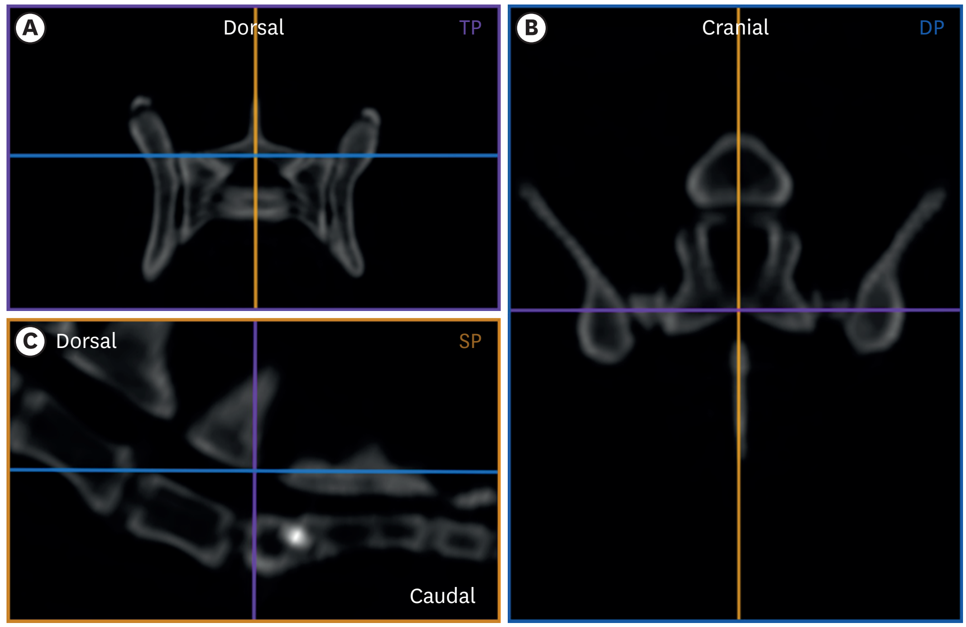

Fig. 6. Computed tomographic view showing sacrum aligned by multiplanar reconstruction. In transverse plane (A) and dorsal plane (B), sagittal plane axises (orange line) are aligned with the spinous process of the L7 and sacrum, respectively. In sagittal plane (C), dorsal plane axis (blue line) is aligned with the floor of the spinal canal of the sacrum.
TP, transverse plane; DP, dorsal plane; SP, sagittal plane.

RESULTS

Evaluation of the pelvic canal widening effect

In every cadaver, the postoperative PCDR (1.26 ± 0.11, range: 1.11 to 1.49) was higher than the preoperative PCDR (1.10 ± 0.12, range: 0.89 to 1.32), and this difference was statistically significant ($p = 0.002$). The mean HCWR was 0.97 ± 0.07 and the range was 0.87 to 1.06. The mean RR was 91.56% ± 7.60% and the range was 78.57% to 100%. (**Table 1**).

Sacral specimen evaluation

The mean SBD was 5.30 ± 0.65 mm (range: 4.06 to 6.04 mm) and the mean sacral body width was 22.73 ± 2.19 mm (range: 18.2 to 26.1 mm) (**Table 2**). No damage was discovered in every sacrum observed on CT except for holes created by the guide wire and screw insertions.

Screw insertion accuracy evaluation

The mean DVA was 2.26° ± 1.33° (range: 0.22° to 5.19°) and the mean CCA was 2.60° ± 1.86° (range 0.70° to 7.01°) (**Table 2**). Every screw was located inside the sacral body except for one cadaver. In cadaver No. 3, the screw penetrated in the dorsal direction, and the screw tip was located in the spinal canal.

Surgical time and technical difficulties

The mean surgical time was 831 ± 302 sec, and the FET was 56 ± 34 sec on average (**Table 2**). The surgical time was the longest in cadaver No. 3 because contact between the drill sleeve and the ilium was difficult due to the large amount of fat in the gluteal region. During the FET, the superimposition of the ilium and the superimposition of the 0.8-mm drill sleeve openings consumed the most time. In particular, the 0.8-mm superimposed round circle was sensitive to the movement of the hand holding the drill sleeve and easily disappeared from the fluoroscopic screen.

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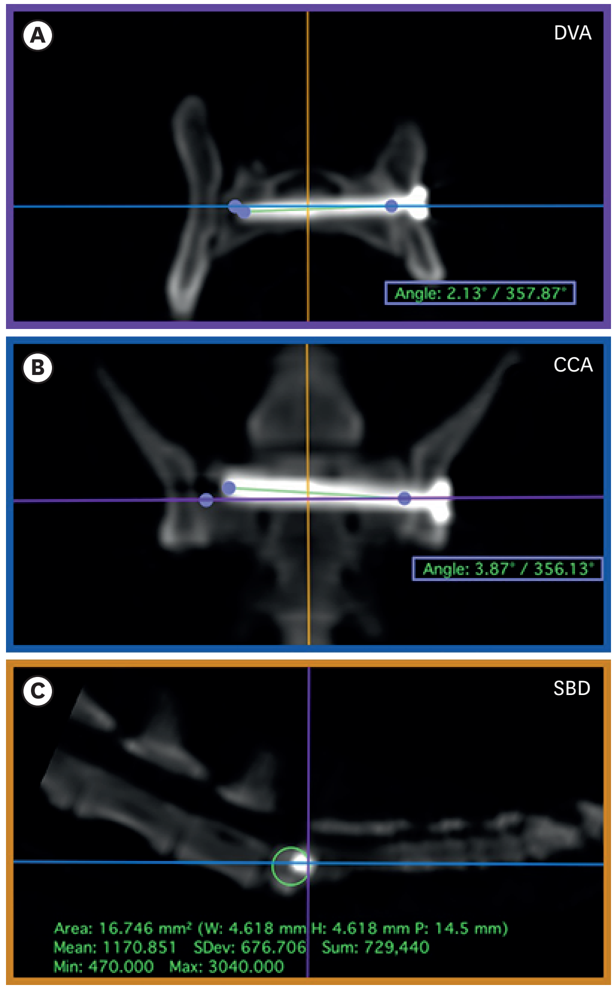

Fig. 7. Measurement of angles of the screw inserted in sacral body and SBD after completion of the alignment of the sacrum via multiplanar reconstruction. DVA is the angle formed by the dorsal plane (blue line) with the screw axis on the transverse plane view (A). CCA is the angle formed by the transverse plane (purple line) with the screw axis on the dorsal plane view (B). On the sagittal plane view, the largest circle that contacts the sacral body boundary is drawn and the diameter of this circle is used as the SBD (C).
SBD, sacral body diameter; DVA, dorsoventral angle; CCA, craniocaudal angle.

Table 1. Results associated with pelvic canal recovery effect after minimally invasive surgical reduction to toy breed dog cadavers

Cadaver No.	PCDR PreOP	PCDR PostOP	HCWR	RR (%)
1	1.32	1.36	1.06	100.00
2	0.89	1.11	0.88	84.27
3	1.12	1.32	1.06	91.47
4	1.13	1.32	1.01	100.00
5	0.95	1.15	1.02	100.00
6	1.20	1.49	1.03	78.57
7	1.10	1.19	0.97	89.05
8	0.98	1.19	0.89	91.66
9	1.03	1.15	0.92	90.96
10	1.18	1.31	0.98	92.15
11	1.12	1.27	0.95	100.00
12	1.19	1.30	0.87	80.57
Mean ± SD	1.10 ± 0.12	1.26 ± 0.11	0.97 ± 0.07	91.56 ± 7.60

PCDR, pelvic canal diameter ratio; OP, operative; HCWR, hemi-pelvic canal width ratio; RR, reduction rate.

Table 2. Results associated with accuracy of screw insertion, cadavers information, and time information after minimally invasive surgical reduction to toy breed dog cadavers

Cadaver No.	DVA (°)	CCA (°)	BW (kg)	SBD (mm)	SBW (mm)	SBE	ST (sec)	FET (sec)
1	3.17	1.13	4.46	5.74	24.2	X	900	78.4
2	1.12	1.04	2.07	4.96	21.6	X	877	60.5
3	3.10	0.78	5.26	5.60	23.7	O	1,590	128.3
4	1.27	1.85	5.40	5.64	25.4	X	740	40.4
5	1.86	0.70	1.55	4.06	18.2	X	547	30.1
6	3.40	1.41	4.32	5.52	22.7	X	774	36.9
7	5.19	7.01	3.05	5.91	21.4	X	709	38.8
8	1.70	3.91	5.32	5.51	24.3	X	738	43.8
9	2.49	3.23	3.17	5.70	22.0	X	445	23.7
10	1.30	2.55	3.28	6.04	26.1	X	917	61.8
11	2.13	3.87	2.97	4.62	20.6	X	1,140	114.6
12	0.22	3.75	3.01	4.29	22.5	X	596	26.1
Mean ± SD	2.26 ± 1.33	2.60 ± 1.86	3.66 ± 1.28	5.30 ± 0.65	22.73 ± 2.19	N/A	831.08 ± 302.38	56.95 ± 34.20

DVA, dorsoventral angle; CCA, craniocaudal angle; BW, body weight; SBD, sacral body diameter; SBW, sacral body width; SBE, sacral body escape; ST, surgical time; FET, fluoroscopic exposure time.

DISCUSSION

Many surgeons have paid attention to the accuracy of screw inserted into the sacral body since the publication of the study [11] that showed that its accurate insertion into the sacrum is critical for successful surgical treatment of sacroiliac luxation. The introduction of a surgical technique by using fluoroscopy clearly improved the accuracy of screw insertion [9,17-20,22]. This surgical technique theoretically guarantees successful surgery if the screw insertion position in the sacrum is directly confirmed and the surgical instruments are accurately handled in line with the position. However, it is natural that the small size of the operated animals, which require accurate manipulation by the operator, hinders the reproducibility of the successful surgery. In this study, accurate insertion of the screw was achieved through a minimally invasive procedure for sacroiliac luxation in dogs with a mean weight of 3.66 kg (min 1.55 kg) and a mean SBD of 5.3 mm (min 4.06 mm). To the author's knowledge, this is the smallest size of dogs so far used in studies.

Dejardin first used the DVA and CCA as indicators to compare the accuracy of screw insertion in the sacrum between the ORIF and the MIS in medium and large dogs [19]. In that study, the mean DVA and CCA of the MIS were 1.6° ± 1.1° and 1.2° ± 0.6°, respectively, indicating very accurate screw insertion results compared to the ORIF (DVA: 7.4° ± 4.9°, CCA: 8.5° ± 5.3°). When the results of this study (DVA: 2.26° ± 1.33°, CCA: 2.60° ± 1.86°) were compared with those of Dejardin, the mean DVA and CCA increased slightly by 0.6° and 1.2°, respectively. It was considered to be due to the small size of the patients and the drill sleeve openings necessary to be aligned with fluoroscopic beam during the surgery. In general, the smaller the size of an object, the lower is the radiographic resolution. Therefore, the possibility of errors in the superimposition of the iliac wings and drill sleeve openings may be higher in the toy breed dog than in the middle and large dogs.

It is known that the PCDR in normal dogs is larger than 1.1 [21], and the PCDR was used in previous studies to evaluate the relative increase of pelvic canal diameter after surgery [17,18,20]. In this study, the postoperative mean PCDR was 1.26 ± 0.11 (range: 1.11 to 1.49), which was not only significantly higher than the preoperative PCDR but it also returned to the normal range in all the cadavers. The closer the HCWR is to 1.0, the more symmetrical is the pelvis [17]. In this study, the mean HCWR was 0.97 ± 0.07, which indicates an almost

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symmetrical pelvis. These two indicators suggested that the surgical technique used in this study has effects in solving the pelvic narrowing due to the sacroiliac luxation in toy breed dogs. These results are similar to the results of previous studies in medium and large sized dogs [17,18].

The SBD is a factor that can influence the technical difficulty of the MIS for sacroiliac luxation. In order to perform the surgery in a dog with a small sacral body, the screws, Kirschner (k)-wire, and drill sleeve must be small. The hand movements of the operator should also be gentle and precise. To date, only a few studies revealed the SBD information of patients. In a study with medium and large dogs, the mean SBD was 9.5 ± 0.8 mm, and the mean SBD of cats in two studies was 5.9 mm [19,23,24]. This study proved that screws can be safely inserted by using the minimally invasive method even in toy breed dogs with a small mean SBD (5.30 ± 0.65 mm, range: 4.0 to 6.04 mm).

In contrast to the previously known MIS for sacroiliac luxation, cannulated screws were used in the present study to improve the suitability in toy breed dogs. In the surgical technique by Tomlinson, a k-wire was inserted into the sacral body caudal to the position to insert the screw for temporary fixation after closed reduction of sacroiliac luxation [17,25]. However, it seems very challenging for the small sacrum of toy breed dogs. Even if the k-wire is successfully inserted, it can interfere with the following surgical procedure due to the small work space. Therefore, a 2.3-mm cannulated screw system was used in this study, which allowed the temporary fixation of the reduction and the accurate screw insertion at the same time. Even though further research on the mechanical properties is required, the cannulated cortical screw has been recommended in the past because the pullout strength and fatigue life of the cannulated cortical screw were not significantly poorer than those of the solid cortical screw [26,27].

The size of the screw to be inserted in the sacral body has an important correlation with postoperative implant failure [17]. There has been no comprehensive study on the appropriate size of screws that showed good prognosis by the patient weight, and only a guideline has been presented [28]. This guideline proposed a 2.7-mm screw for 2.5 to 12.5 kg of patient weight but the weight range in this study was 1.55 to 5.4 kg, and a 2.4-mm screw was used in a previous study on cats by applying the AO recommendations to SBD [20]. Based on these previous observations, it was considered that a 2.3-mm screw was acceptable.

The screws used in this study were selected in line with the widths of sacrum and ilium, but they were partial thread screws whose screw thread length/sacral width ratio did not meet the minimum criterion of 60% suggested in previous studies [11]. However, Tonks argued that in the case of the MIS, there is no need to satisfy the existing criterion that the screw length/sacral width ratio should be more than 60% because of the effect of the peripheral soft tissues that were not surgically cut [18]. Based on Tonks's argument, further research with actual cases is required to investigate how the surgical technique used in this study would resist screw loosening.

The characteristic and potential disadvantage of the MIS of sacroiliac luxation is radiation exposure. In this study, the factors that increased the mean FET were the confirmation of the superimposition of iliac wing and the technical difficulty experienced while superimposing the 0.8-mm drill sleeve openings. Despite these factors, considering that the FETs of interventional procedures published in the medical circles are usually longer than 7 minutes

[29], the mean FET of this study (56 ± 34 sec) is acceptable and seems to be not too long to pose an issue. However, the minimal use of fluoroscopy should be recommended to reduce the potential risk of patients and all the staff in the operation room.

This study has a few limitations. First, the MIS of sacroiliac luxation can be easier to apply to cadavers than to living participants. The reduction of sacroiliac luxation in cadavers is easier when compared to reduction in patients to be encountered in clinics. Moreover, because there was no bleeding during the surgery, the operator could concentrate on accurate screw insertion and this could shorten the surgical time. Second, no evaluation of biomechanical performance of a cannulated screw was performed in living dogs. Follow-up studies for biomechanical test must be conducted before applying the technique to clinical cases.

This study, for the first time, proved the effectiveness and reproducibility of the MIS of sacroiliac luxation in toy breed dogs. Although the superimposition of 0.8-mm drill sleeve openings requires some level of proficiency, the findings of this study would support the applicability of the MIS of sacroiliac luxation in toy breed dogs and could contribute to the improvement of surgical outcomes in toy breed dog patients with sacroiliac luxation.

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