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CASE REPORT

Stabilization of traumatic thoracolumbar subluxation using patient-specific drill guide with double pin and polymethylmethacrylate in a 12-year-old Maltese dog

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ABSTRACT. Spinal instability in a 12-year-old Maltese with T11-12 subluxation presenting with neurological symptoms, including hindlimb paraplegia, was treated using double-pin and polymethyl methacrylate (PMMA) fixation. Postoperatively, neurological deficits and hindlimb paraplegia improved, enabling the dog to regain independent ambulation without assistance. Patient-specific drill guides enhanced the accuracy and safety of screw placement, highlighting their potential as an effective method for managing thoracolumbar subluxations in veterinary medicine.

Keywords: Thoracolumbar subluxation, locomotor recovery, PMMA, guide, dog.

Spinal instability in dogs is a progressive condition that can result from degenerative, traumatic, or congenital causes, characterized by dynamic or static compression of the spinal cord due to abnormalities in the vertebrae and/or surrounding soft tissues (Trotter, 2009; Aikawa *et al*., 2007). The clinical signs include pain, ataxia, paresis, paralysis, or a combination of these. When clinical signs progress to the point at which quality of life is substantially compromised, surgical intervention may be considered. Spinal cord decompression followed by vertebral fixation techniques is the treatment of choice for severe cases (Steffen *et al*., 2011). Various methods for internal and external vertebral fixation have been reported (Agnello *et al*., 2010; Auger *et al*., 2000; Downes *et al*., 2009; Garcia *et al*., 1994; Nel *et al*., 2017; Meij *et al*., 2007; Smolders *et al*., 2012). Vertebral fixation is accomplished using implants, such as pins or screws, placed within the pedicles or vertebral bodies, along with polymethyl methacrylate (PMMA), stainless steel, or titanium plates (Sturges *et al*., 2016; Hall *et al*., 2015). These surgical methods provide rigid and immediate intervertebral fixation, which results in satisfactory outcomes in most clinical cases. However, they also carry the potential risk of iatrogenic injury to vital structures, including the spinal cord, nerve roots, and vasculature. The increased cost of this equipment is likely to contribute to its limited adoption in veterinary medicine. Consequently, freehand implant placement remains common during spinal fixation surgery. However, freehand implantation may result in iatrogenic injury to the spinal cord, nerve roots, and large vessels, potentially leading to serious complications (Hamilton-Bennett *et al*., 2018). The increasing availability of computed tomography (CT) in veterinary practice, along with advancements in computer-aided design and manufacturing technologies, has prompted us to evaluate these technologies for spinal fixation surgery in dogs.

The objective of this report was to detail the management technique for T11-T12 subluxation using a patient-specific drill guide, along with the short-term outcomes observed. The surgical approach involved the application of a double-pin and PMMA constructs to the affected vertebral segments.

A 12-year-old, 3 kg spayed female Maltese dog was referred to the Jeonbuk National University Animal Medical Center for evaluation of bite wounds with thoracolumbar pain and hindlimb paraplegia. The Texas Spinal Cord Injury Score (TSCIS; Levine *et al*., 2009). was assessed for all four limbs, resulting in a total score of 16. Both forelimbs demonstrated gait scores of 6, proprioceptive positioning scores of 2, and nociception scores of 2. In contrast, both hindlimbs scored 0 for gait, proprioceptive positioning, and nociception.

The referring veterinarian confirmed T11-12 subluxation and treated the dog with oxygen therapy for 2 days; however, the dog's condition deteriorated, and she became recumbent. Upon presentation, physical and neurological examination revealed nonambulatory hindlimb paraplegia. Mentation and cranial nerve reflexes were normal. Palpation of the thoracolumbar spine between the T11 and T12 vertebrae elicited severe pain. Upon hospitalization, deep pain sensation was present only in the forelimb but was subsequently regained during the hospital stay. No further neurological examinations were conducted, as the radiographs indicated definitive subluxation at T11-12. A complete blood count revealed moderate anemia (HCT, 25.8%; reference range: 37.3-61.7%). Thoracic radiography revealed an alveolar pattern in the left cranial lung lobe. Considering the decreased hematocrit levels and the absence of evidence for active bleeding in other regions, pulmonary hemorrhage was strongly suspected. Intensive cage rest and supplemental oxygen therapy were initiated to stabilize the patient's condition. The following day, CT and magnetic resonance imaging (MRI), performed under general anesthesia, confirmed the presence of spinal cord compression (Figure 1).

Owing to the progression of neurological deficits and lack of response to conservative treatment for 1-week, surgical treatment was recommended. The patient-specific drill guide was designed based on preoperative CT images, which provided three-dimensional representations of the bones and surrounding vasculature, allowing for precise determination of the pin insertion trajectory. After obtaining the CT images of the thoracic vertebrae to be corrected, the guide was designed using computer-aided design software (Fusion 360, Autodesk, San Rafael, CA, USA). This software facilitated the design of the drill guide with the necessary angles for pin insertion. The design of the drill guide incorporated several unique features. First, a handle was added to the body of the guide to enhance the ease of use. Second, sufficient clearance was provided between the guide and the vertebral body to ensure accurate placement. Additionally, the guide was designed to be fixed to the vertebra by fitting it onto the spinous process from posterior to anterior. Third, unlike conventional methods in which one pin is typically placed on each side of the vertebral body for stabilization, the drill guide used in this case involved placing two smaller pins on each side of the vertebra, resulting in a total of eight pins for stabilization (Figure 2). The designed guide was 3D-printed using a dental surgical guide resin (ZMD-1000B CLEAR-SG, Zenith, Daegu, Republic of Korea) with a resin 3D printer (Pixel One, Zerone, Gyeonggi, Republic of Korea).

The dog received preoperative medication including amoxicillin-clavulanate (13.5 mg/kg, IV), fentanyl (1 μg/kg, IV), ketamine (0.5 mg/kg, IV), lidocaine (2 mg/kg, IV), and midazolam (0.2 mg/kg, IV). Anesthesia was induced with propofol (4 mg/kg, IV) and maintained with sevoflurane inhalation. The surgical site was then clipped and prepared for aseptic surgery. All limbs were retracted laterally in a ventral recumbent position. The thoracic vertebrae to be stabilized were exposed via a bilateral dorsal approach. Point-to-point reduction forceps were clamped on the spinous process to apply careful dorsal and slight caudal traction of T11 until alignment appeared normal. The reduction was temporarily maintained by placing a 1.2 mm Kirschner wire across the articular processes of the T11-12 joint. Care was taken to optimize the guide fit to elevate all soft tissues from the cortices in the guide footprint region. A portion of the drill guide footprint incorporated the dorsal process; however, to access the vertebra, the dorsal process of the more cranial vertebrae had to be removed because it impeded drill guide placement (Figure 2). Therefore, the dorsal processes were removed sequentially (cranially to caudally) to allow for the placement of the drill guides and the drilling of the pilot holes. Double bi-cortical thread pins were subsequently placed, leaving an appropriate portion protruding from the cortex (typically 6-10 mm) for PMMA bonding. After PMMA fixation, the tissue was flushed with cold saline to prevent thermal injury due to solidification, and the pins that pierced

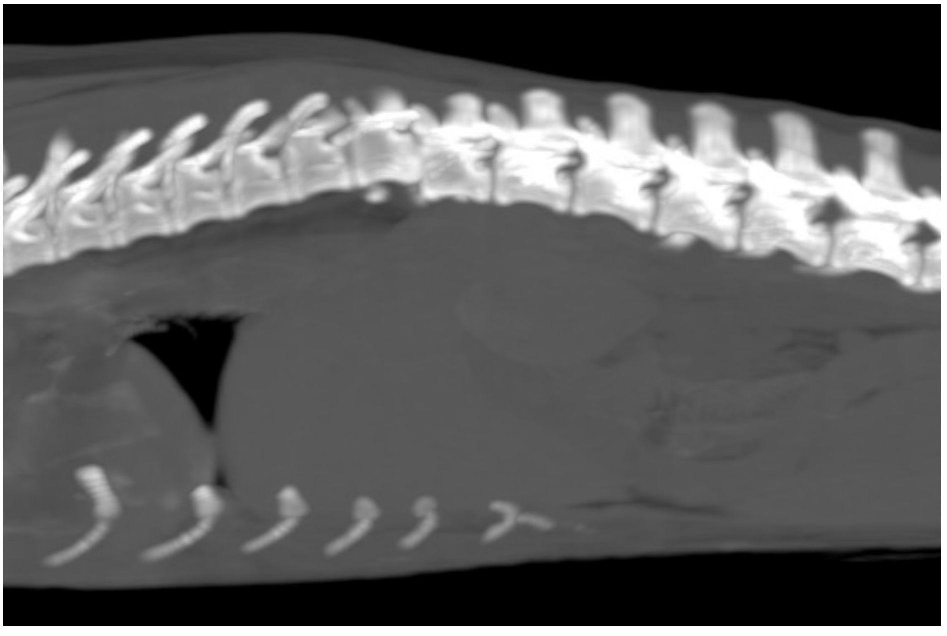

Figure 1.
Sagittal view of the thoracolumbar spine obtained via preoperative computed tomography (CT), demonstrating a significant subluxation at the T11-T12 vertebral junction. The image illustrates the displacement between the T11 and T12 vertebrae.

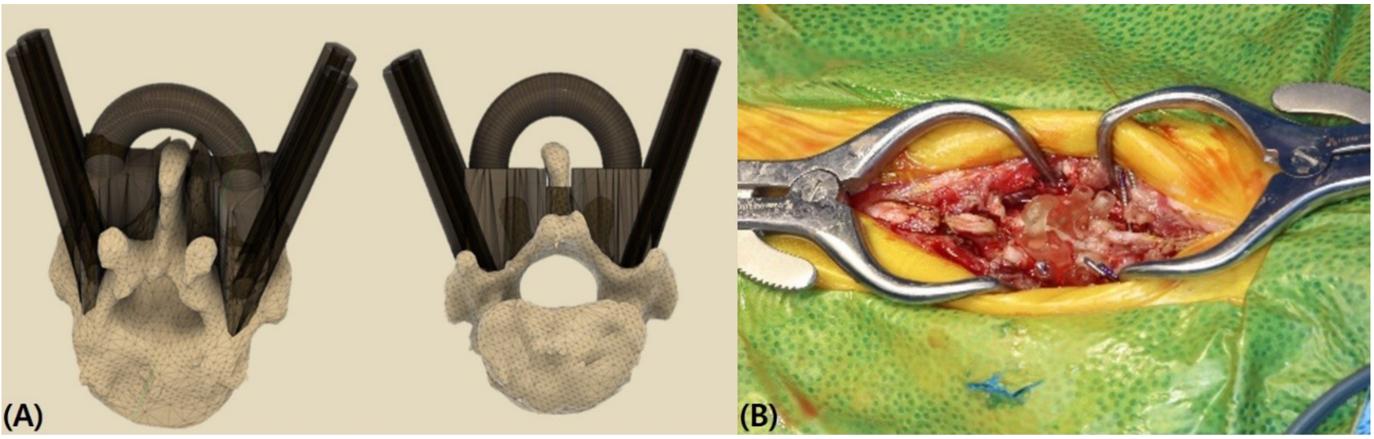

Figure 2.
(A) Three-dimensional rendering of the patient-specific drill guide and pin placement for stabilization of the T11-T12 vertebral segment. (B) Intraoperative image showing the placement of the patient-specific drill guide on the T11-T12 vertebrae during the surgical procedure.

the bone cement were trimmed (Butto *et al*., 2018). Closure of the muscle and skin layers was routinely performed. The realignment of the vertebrae was adequate in the postoperative radiographs (Figure 3), and CT of the region was performed postoperatively (Figure 4).

The dog was treated with amoxicillin-clavulanate (20 mg/kg, BID, PO), metronidazole (15 mg/kg, BID, PO), omeprazole (1 mg/kg, SID, PO), and silymarin (10 mg/kg, BID, PO) for three weeks. Postoperatively, the dog showed progressive neurological recovery. By day 16, the dog could stand independently, with forelimb TSCIS (Levine *et al*., 2009) scores of gait of 6, proprioceptive positioning of 2, and nociception of 2, and hindlimb scores improving to gait of 4, proprioceptive positioning of 1, and nociception of 2. After four weeks, the dog was ambulatory for 5-10 minutes, with further improvement in hindlimb function, achieving gait 4, proprioceptive positioning 2, and nociception 2 in the hindlimbs.

Six weeks after surgery, radiographs confirmed adequate alignment and bone fusion at T11 and T12. Hindlimb function improved, with TSCIS scores of gait of 5, proprioceptive positioning of 2, and nociception of 2. Although mild ataxia persisted, the owner reported significant improvement in the dog's walking ability and expressed satisfaction with the surgical outcomes. Follow-up beyond 6 weeks postopera-

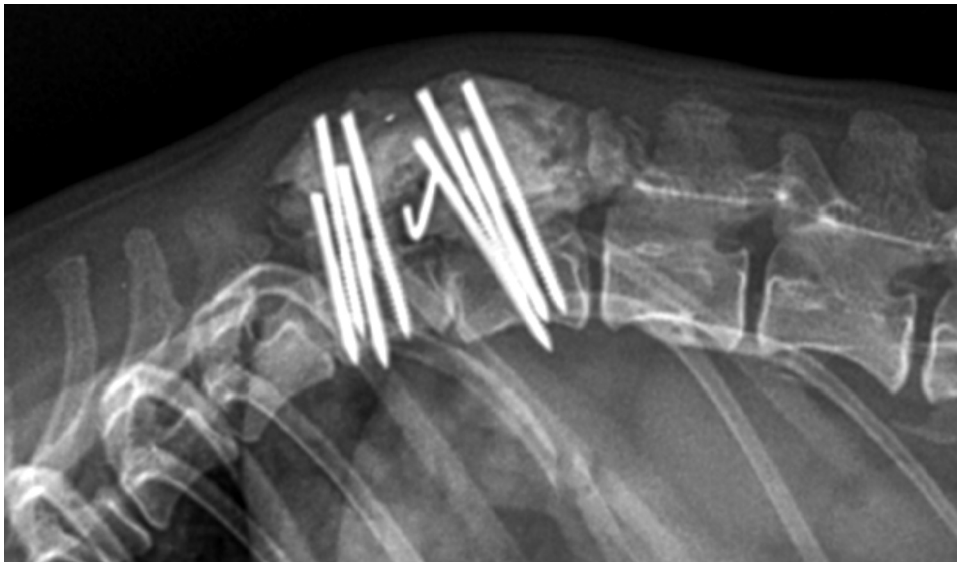

Figure 3.
Left lateral radiograph of the thorax of the dog, demonstrating the correct placement of pins. The mean screw deviation was 1.16 ± 0.56 mm, with 87.5% of screws (7 out of 8) placed accurately without breaching the vertebral canal.

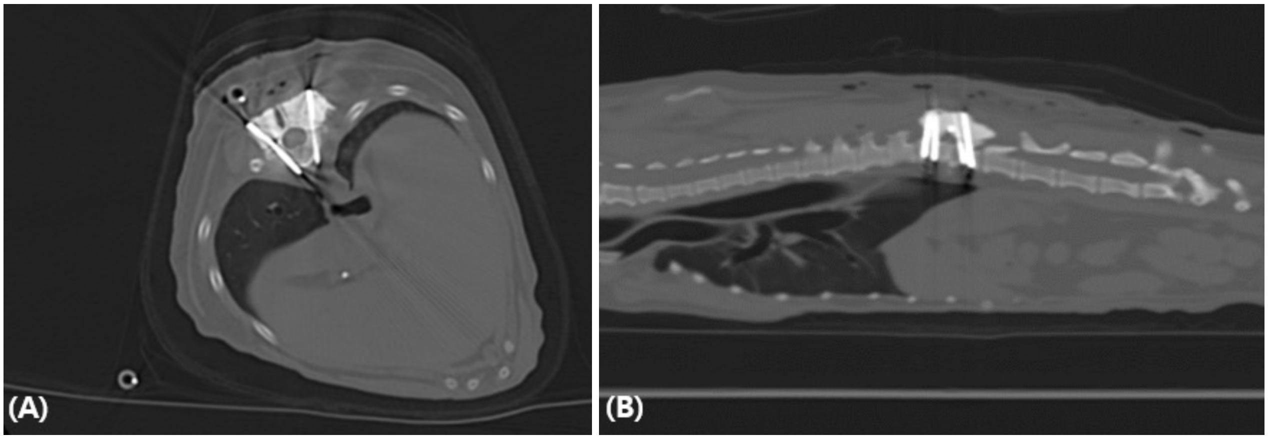

Figure 4.
Postoperative computed tomography (CT) images of the thorax and abdomen. (A) Transverse plane showing the placement of stabilization pins in the T11-T12 vertebral segment. (B) Sagittal plane image displaying the alignment of the vertebral bodies and the fixation construct post-surgery.

tively was not conducted because of external circumstances involving the owner.

Surgical treatment modalities for stabilizing thoracolumbar vertebral luxation have been comprehensively documented in the literature, including techniques such as pin and PMMA fixation, vertebral plate fixation, external skeletal fixation, and spinal stapling (Hettlich, 2017). In this case, a patient-specific drill guide system was employed to stabilize the T11-T12 vertebral luxation. Unlike conventional methods, which typically require the placement of two pins on each side of the vertebra for T11-T12 stabilization, our approach utilized two smaller pins on each side of the vertebra, resulting in a total of eight pins (Figure 2 and 3). This technique, involving the placement of double pins on both the left and right sides of T11 and T12, enhances the precision and stability of the fixation, while reducing the risk of cortical penetration of the pedicles. By applying this method, the objective was to improve the overall strength of the fixation, ensure accurate placement of screws, and achieve more stable stabilization. The pins were inserted through the pedicles into the vertebral bodies, thereby optimizing the stability of the construct.

The accuracy of this approach was evaluated, yielding a mean screw deviation of 1.16 ± 0.56 mm, with 87.5% of screws (7 out of 8) placed accurately without breaching the vertebral canal. A potential factor contributing to screw misdirection (grade 2) was identified as an alteration in the drill sleeve angle due to the load on the drill bit during the drilling procedure (Zdichavsky *et al*., 2004). Additionally, the use of patient-specific drill guide templates designed using preoperative CT data significantly mitigated the risk of major vessel injury. The current case exhibited satisfactory short-term clinical outcomes with no significant complications.

This study had several limitations. First, the outcomes were only evaluated up to six weeks post-surgery, limiting the ability to assess the long-term effects and stability of the intervention. Further long-term follow-up is needed to fully understand the recovery and potential complications. Second, the use of patient-specific drill guides requires costly equipment and specialized software, which may limit accessibility in some veterinary practices. Future research should explore more cost-effective alternatives and methods to enhance the accessibility of these technologies for wider use. Although expert physiotherapy techniques, such as laser therapy and electroacupuncture, are routinely employed in our practice for neurological cases to optimize recovery, they were not utilized in this case owing to financial and time constraints imposed by the owner. Despite strong recommendations for these treatments, their absence did not appear to adversely affect the short-term outcomes. However, the inclusion of physiotherapy support could potentially enhance the recovery process. Future studies incorporating physiotherapy in conjunction with surgical intervention may provide valuable insights into its combined effects on recovery in similar cases.

In conclusion, this case underscores the potential utility of patient-specific drill guide templates in improving the precision and safety of screw placement for the management of thoracolumbar vertebral luxation, as well as the observed enhancement in clinical outcomes, including functional recovery of movement and mobility. Additionally, the technique of placing double pins within a single vertebra appears to play a role in minimizing the risk of cortical penetration of the vertebral bone. However, the limitations of this study include the short-term follow-up period and the cost and accessibility of the necessary equipment. These findings suggest that, while patient-specific drill guide templates and double-pin placement techniques may offer a promising and effective therapeutic strategy, further long-term studies are warranted.

DECLARATIONS

Competing Interests Statement

The authors declare that they have no competing interests.

Author Contributions

Conceptualization: Yi KW, K IG; Data curation: Yi KW; Investigation: Yi KW; Supervision: Heo SY; Writing - original draft: Yi KW; Writing - review & editing: Heo SY.

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