Spinal Fractures - Extreme Problem Solving

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Keywords: Spine, Fracture, Pedicle Screw, Bone Cement

1. Introduction

Fractures of the spinal column are often looked at with trepidation. And they should be. A knowledge of neuroanatomy, neurological function, advanced imaging interpretation and prognostication based on etiology of the injury and examination of the patient is necessary to begin. Then we have to take into consideration the surgeon's comfort level and skill with placing implants in the spinal column, as well as, immediate and long-term post operative care of the patient for a successful outcome. Poly trauma, including multiple fracture or subluxation locations, often accompanies spinal fractures. Adequate assessment of the patient's vital systems is also required. The patient should be metabolically stable prior to spinal stabilization (i.e. capable of handling a long anesthesia). There are multiple techniques used to stabilize the spinal column, depending on the area affected. The surgeon should use the technique they are most comfortable with, assuming there is a reasonably good outcome the technique will be beneficial to the patient. In many instances, routine surgical stabilization techniques used on other portions of the body (i.e. various orthopedic plates) can be used in the spinal fracture cases and in some cases, different techniques can (and should) be combined. The goals of this presentation are to provide the learner with various techniques the author has used to treat spinal fractures in dogs and cats.

2. Incidence, Location and Etiology (Briefly)

The most common location for a spinal fracture / subluxation is the thoracolumbar area of the spine. 50% of all fractures in dogs and cats will occur between T10 – L2[1-2]. 12-20% of fracture / subluxations will occur in the cervical spine and within the cervical spine, 52 – 78% will occur at C2[3-6]. Causes of fracture / subluxation include trauma (motor vehicle, acute deceleration injuries, fall from great heights, etc.), pathological fractures secondary to diseased tissue (i.e. neoplasia) and iatrogenic fractures / subluxations (e.g. instability) created by a routine and advanced decompressive spinal surgery[3].

Surgery, possibly including stabilization, would be indicated where instability is present, for neural tissue decompression and for pain that does not resolve with conservative management. An excellent review of stabilization indications is available[7]. The goals of surgery are therefore:

- Stabile reduction
- Reduction / elimination of compression
- No iatrogenic trauma

The prognosis is highly dependent on the cause of the injury, the location of the injury, the neurological status, the treatment provided and the post-surgical aftercare. Therefore, what we are relying on is a knowledge of the anatomy, knowing what we can get away with and picking various techniques to solve the problem. There are many, many ways to stabilize the spine and a review is beyond the scope of these proceedings. This discussion will focus on implant corridors, construct construction, the use of commonly available materials and specialized implants, specifically designed for spinal stabilization. Ultimately, the surgeon should use the technique they are most comfortable with.

3. Diagnosis

A diagnosis of spinal fracture / subluxation is commonly made with plain film radiographs, followed by advanced imaging, which may include magnetic resonance imaging (MRI), computed tomography (CT) or both. The author prefers all three modalities but often settles for radiographs and MRI. MRI is essential to determine if spinal cord compression is present in the form of hemorrhage, extruded disk material, foreign body material, infectious tissue and fragments of bone or other adjacent soft tissues. MRI also provides for visualization of parenchymal damage, which may alter prognosis. MRI allows for evaluation of adjacent soft tissue damage. If MRI is not available, CT scans are a reasonable alternative. CT scans also aid tremendously in surgical planning. Surgical planning can be performed with MRI images, particularly T1 – weighted sequences, where the bony anatomy is best visualized.

4. Treatment

Numerous techniques have been described relating to spinal stabilization. For this discussion, we will focus on two techniques. 1. The use of cortical bone screws, "rebar" and polymethylmethacrylate (PMMA)[8]. 2. Polyaxial or "pedicle" screws. Any construct should utilize the largest screw possible at the greatest screw depth possible within reason. Generally, a ratio of screw diameter to pedicle width should be ~80%. Whereas bone depth should be at least greater than 50%[9-10]. Where possible, the construct should be placed to oppose the major forces applied to that portion of the spine and ideally two vertebral motion units above and below the unstable area[11].

4.1 Screws, Pins and PMMA

This technique can be applied to any portion of the spinal column (Fig. 1). It utilizes commonly found materials in any surgical practice, is inexpensive, has a significant degree of engineering and is durable. It is a common technique used by the author to stabilize the atlantoaxial and lumbosacral spaces and the basic idea can be applied to any form of spinal stabilization[8] (Fig 2). Briefly, cortical bone screws are placed in predefined implant corridors. A portion of the screw is left "proud" in order to accept a cut stainless steel pin on the underside of the screw head. The pin is wired to the screw head with cerclage wire with the portion of the spine in temporary reduction. The pin acts as rebar to resist bending tensile forces placed on PMMA. PMMA, in the consistency of honey (where possible) or soft pizza dough (where not possible) is applied to the implant, making sure all metallic potions are covered (but being careful not to use excessive amounts of PMMA) and allowed to cure. The final construct is robust and durable (Fig. 3). PMMA and screws may be used alone without rebar, in cases where the PMMA construct is small. In cases where the PMMA use is extensive (a length greater than 3 cm), the author will incorporate cut pins, wired to the protruding screw heads in order to lessen the chance of PMMA fracture secondary to bending forces. PMMA, like concrete is resistant to compressive forces but susceptible to bending and rotational forces. Rebar counters these forces.

Disadvantages of this technique include the use of PMMA, and the length of time required to build the construct, when compared to other techniques such as the use of locking plates, positive profile pins and PMMA and polyaxial screws. Most commonly, screw, bar and PMMA constructs are made from stainless steel. While titanium screws and rods are available, titanium rods are brittle and do not have as high of a tensile strength as stainless steel. Stainless steel rods are more malleable and ductile, making them easier to bend without cracking or breaking. However, stainless steel creates a significant magnetic susceptibility artifact making post operative MRI imaging not possible at the site of the implant. Another limiting factor in the design of the consult is the surgeon's ability to "build things."

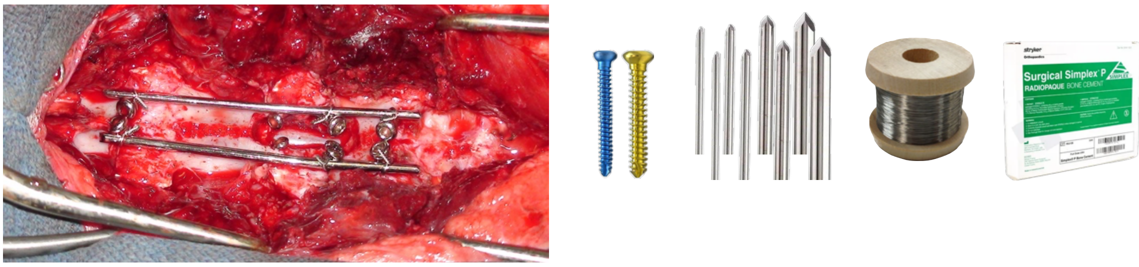


Fig. 1. A spinal construct created from inexpensive, readily available components, including cortical bone screws, Steinmann pins, Cerclage wire and polymethylmethacrylate can be engineered to any portion of the canine or feline spine.

4.2 Polyaxial screws

Polyaxial screws (PAS) have been used for decades as the primary treatment for human spinal stabilization. In the last ten years, various companies have provided veterinary specific PAS. These implants are comprised of a screw, a "tulip" which accepts a connecting bar and a locking cap that affixes the bar to the tulip. The rotating tulip affords various degrees of offset from the plane of insertion (typically 25 – 35 degrees). This allows the screws the ability to create a construct in nearly all areas of the spine, limited only by the size of the implant and certain anatomic areas (such as the atlantoaxial space). Current applications allow placement in the dorsal cervical spine, ventral cervical spine (large dogs), thoracic, lumbar and lumbosacral spine. Screws can be inserted in any common corridor but have their greatest application when inserted in the pedicles and vertebral bodies. In the thoracic spine (T1 – ~T12) they are inserted into the pedicle. In the lumbar spine and upper thoracic (T13 – L6) they can be inserted into the vertebral body or the pedicle. At L7 and S1-S2, they can only be inserted into the pedicle.

Advantages of PAS include, rapidity of application, elimination of the need for PMMA and the ability to be applied to most areas of the spine. Because they are generally made from titanium, post operative MRI is going to have a better image quality with very little magnetic susceptibility artifact.

Disadvantages of PAS include, steep learning curve (especially in the thoracic spine), limited engineering (when compared to screws, pins and PMMA) and cost.

The author now prefers to use PAS where possible in lieu screws, pins and PMMA. Their use is dictated by a) the client's ability to afford the implants (currently ~ $270.00 -US / per screw), b) the available screw sizes for various sizes of dogs and cats (generally more available for dogs larger than 15kg.

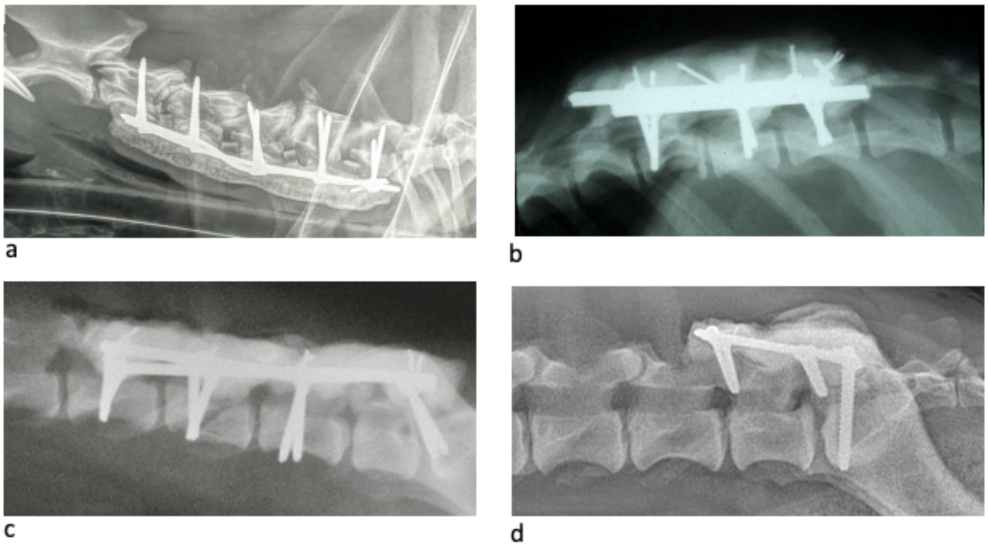


Fig. 2 a) Ventral dorsal pedicle screw with vertebroplasty for cervical spondylomyelopathy. b) Thoracic fracture stabilization. c) Lumbar fracture stabilization d) Lumbosacral distraction / stabilization for degenerative lumbosacral stenosis.

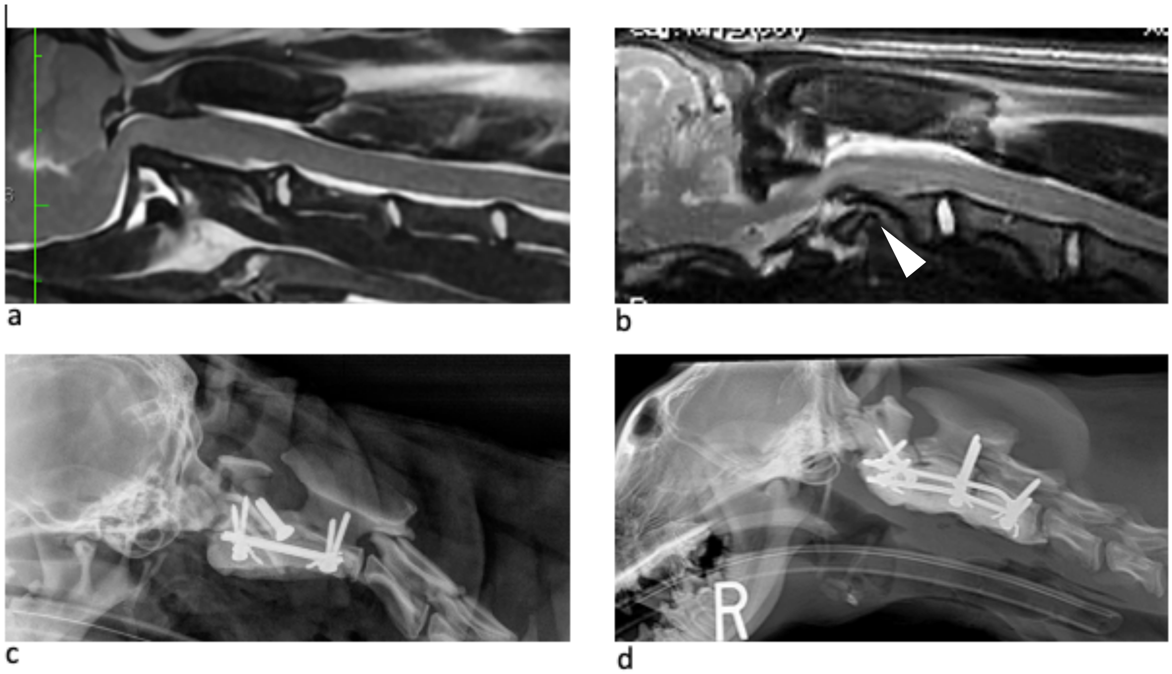


Fig. 3. a) Sagittal, T2 – weighted, MRI of a dog with atlantoaxial instability. b) Sagittal, T2 – weighted, MRI of a dog with a C2 vertebral body fracture (arrow). c) Same dog in (a) following surgical stabilization using screws, pins and PMMA. d) Same dog as in (b) following

reduction and stabilization using similar technique to (c). The dog in a-c was a Cavalier King Charles Spaniel. The dog in b-d was an 8-month-old Husky.

5. Implant Corridors

5.1 Cervical spine

Screws can be placed at divergent angles in the lateral mass (pedicle) of C1 (monocortical or bicortical) and the wings of the atlas (bicortical). Screws at C2 are placed in the cranial articular masses (divergent monocortical or transarticular), in the pedicles of C2 (divergent, bicortical), the caudal vertebral body (convergent, monocortical) or the transverse processes (divergent, bicortical).

For C3 – C7, screws can be placed in the pedicles, transverse processes or vertebral bodies (monocortical). Other than the vertebral bodies, screws are at divergent angles from the spine. When placing a screw in the transverse process or pedicle there is risk of entering the vertebral foramen. Significant hemorrhage will likely be encountered. If this occurs, place the screw, with a small amount of bone wax applied to the treads midway, into the drilled hole. The hemorrhage should stop as the screw is tightened and the bone wax creates a seal between the screw and the bone. There is significant collateral circulation in the cervical spine (fig 4)[12].

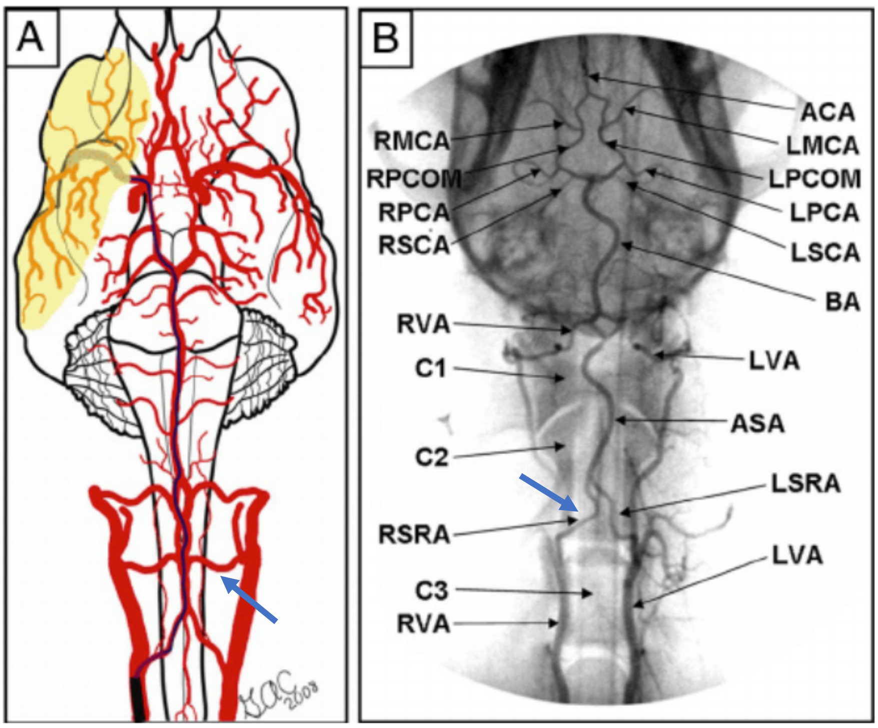


Fig. 4. The ramus spinals artery (RSRA) connects vertebral arteries (arrows). Occluding one or even both sides does not cut off blood supply to the basilar artery. It is a highly redundant system. From Rinc, C. 2008[12].

5.2 Thoracic Spine

Identifying the transverse process, just medial to the mamillary body is the key to thoracic spine screw placement. Pre-operative CT scans with the ability to perform multi-planar reconstruction will aid the planning process, provide dimensions for screw sizing and depth of insertion, as well as angle of insertion. Hand drilling with fixed depth drill bits or using a drill stop on a drill bit will lessen the chance of iatrogenic damage. Screws are placed perpendicular to slightly convergent depending on the anatomy (Fig 5). Screws should be monocortical to avoid entering the thoracic cavity. Prior to placing screws, hole depth and integrity should be evaluated for breach (lateral or medial).

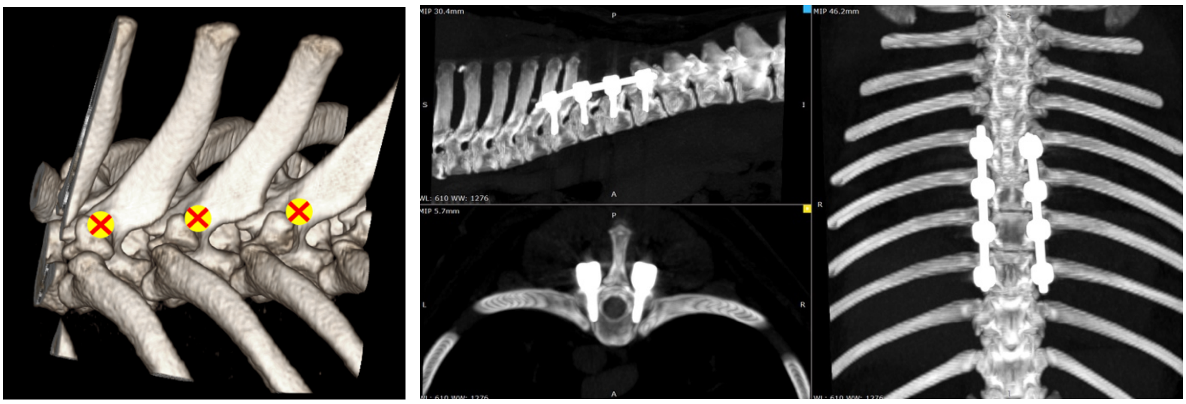


Fig 5. In the thoracic spine, screws are placed in the transverse process, just medial to the mamillary body at perpendicular to slightly convergent angles.

5.3 L1 – L6

The least challenging area to place screws is L1 – L6. Here, we have the option, depending on the size of the patient and its anatomy, to place, facet, pedicle or body screws (Fig. 6). Facet screws can be nearly as strong as pedicle screws in countering flexion/extension forces (at least in human cadaver studies)[13]. One thing to try and avoid is the mixing of both pedicle screws and body screws in the same construct in large dogs. The difference in angle and height makes bending the connecting bar (usually a 5.5 mm bar) difficult, especially if the connecting bar is made of titanium. If you find yourself in the situation where the mixture is the only option (i.e. pedicle screw adjacent to body screw), consider the use of a Steinmann pin in place of a titanium rod for polyaxial screw connection. The stainless steel of the pin is more ductile and malleable and is therefore much easier to bend. Screws can be monocortical or bicortical but the surgeon should be aware of distant structures, on the opposite side of the bone, such as nerve roots and important vasculature. Body screws should be offset slightly (one side angled slightly cranial and the opposite side angled slightly caudal), so the tips do not meet within the vertebral body.

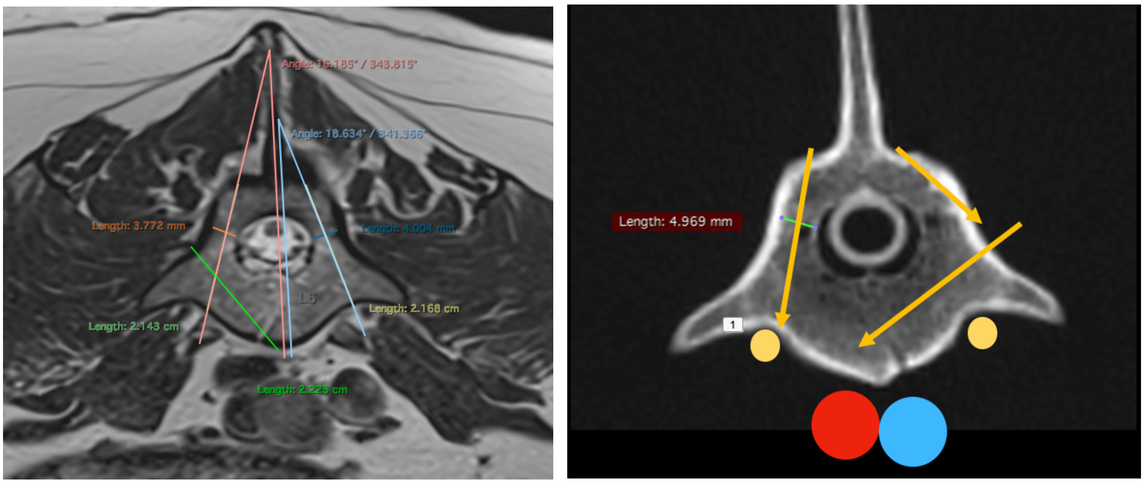
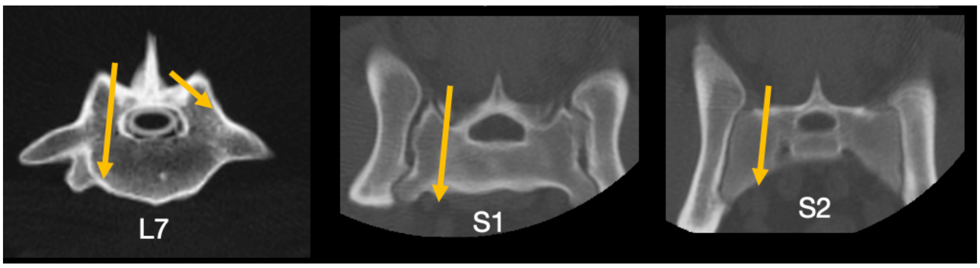


Fig 6. In the L1 – L6 spinal column, screws can be placed in transverse process, the pedicle and the vertebral body. Note the position of important elements of the anatomy when placing bicortical screws.

Screws placed in L7 and the sacrum are limited to the articular facets and pedicles of L7 and the pedicles of S1 – S2. Screws can be monocortical or bicortical as long as distal anatomy is not damaged (Fig. 6 and 7). Screws in the L7 – S1 facet can be very useful for maintaining spine reduction until the complete implant is constructed. Study the anatomy closely and if possible, use a pre-operative CT to reconstruct the spine and plan accordingly. As always, be ready and willing to improvise. The pedicles of S1 and S2 are rather close to one another so make sure you have adequate room for polyaxial screw heads (tulips) in this area. The tulips should be able to turn freely. Make sure the screw head is as close to the bone as possible to avoid creating a large moment arm, which will make the screw more susceptible to breaking.



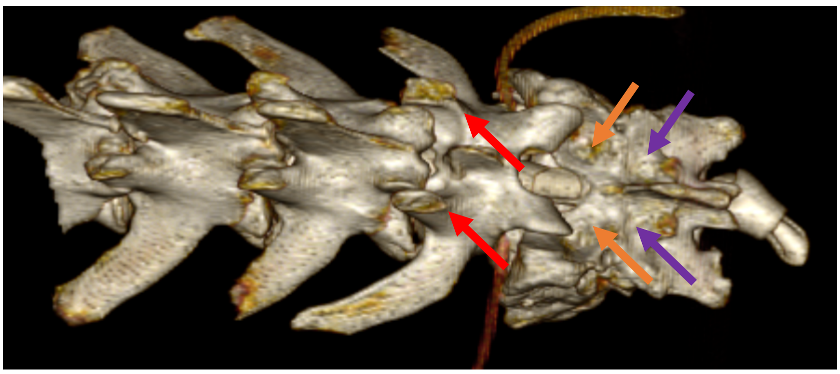


Fig. 7. At L7, because of the ilium, screws are mainly placed in the pedicles and the facets (pedicles = red arrows). At S and S2, screws are placed in the pedicles. Study the anatomy carefully to identify screw corridors. The pedicle of S1 is located just behind the articulation of L7 – S1 in a fossa (orange arrows). The pedicle for S2 is just behind the intermediate sagittal crest (purple arrows). Make sure if you are using polyaxial screws, there is enough room for the tulips, which will be quite close to one another.

6. Conclusion

It is important for the surgeon to deliberate all options when considering spinal stabilization for fracture and/or subluxation. It is beyond the scope of this presentation to provide all the answers. When it comes to biomechanics, trust your gut and make the construct strong. Consider the "belts and suspenders" approach for redundancy. If it looks right, it probably is. Use CT combined with MRI to determine if there is spinal cord compression and to help in planning the surgery and be ready to improvise. Use the method or technique you are most comfortable with but do not be afraid to mix techniques. A cuttable plate was used to problem solve in two C2 fractures[14]. The plate was used to reduce the fracture and also served as a reinforcing bar when incorporated into the bone cement. This is a prime example of improvisation (Fig. 8).

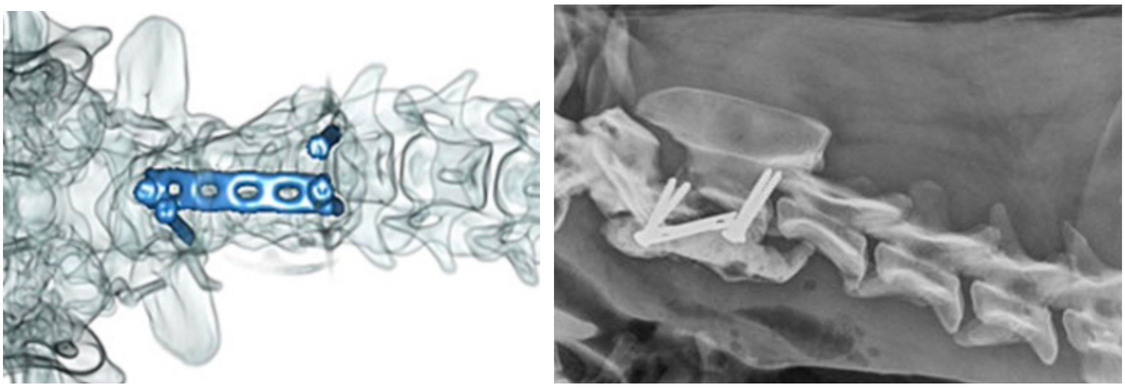


Fig. 8. A cuttable plate is used as a lever to reduce and hold into position a C2 fracture until polymethylmethacrylate can cure. A fine example of improvisation and problem solving. Image courtesy of Dr. Kark Kraus, ACVS. From: Snead OM, Law AY, MacRae MR, Yoder HR, Kraus KH. Case Report: Use of veterinary cuttable plates to maintain reduction and reinforce polymethylmethacrylate (PMMA) fixation in two canine C2 vertebral fractures. Front Vet Sci. 2025 Apr 30;12:1534966. doi: 10.3389/fvets.2025.1534966. PMID: 40370826; PMCID: PMC12075552.

References

1. Jeffery ND. Vertebral fracture and luxation in small animals. Vet Clin North Am Small Anim Pract. 2010 Sep;40(5):809-28. doi: 10.1016/j.cvsm.2010.05.004. PMID: 20732593.

2. Bali MS, Lang J, Jaggy A, Spreng D, Doherr MG, Forterre F. Comparative study of vertebral fractures and luxations in dogs and cats. Vet Comp Orthop Traumatol. 2009;22(1):47-53. PMID: 19151870.
3. Bruce CW, Brisson BA, Gyselinck K. Spinal fracture and luxation in dogs and cats: a retrospective evaluation of 95 cases. Vet Comp Orthop Traumatol. 2008;21(3):280-4. PMID: 18536856.
4. Hawthorne JC, Blevins WE, Wallace LJ, Glickman N, Waters DJ. Cervical vertebral fractures in 56 dogs: a retrospective study. J Am Anim Hosp Assoc. 1999 Mar-Apr;35(2):135-46. doi: 10.5326/15473317-35-2-135. PMID: 10102182.
5. Pike FS, Kumar MS, Boudrieau RJ. Reduction and fixation of cranial cervical fracture/luxations using screws and polymethylmethacrylate (PMMA) cement: a distraction technique applied to the base of the skull in thirteen dogs. Vet Surg. 2012 Feb;41(2):235-47. doi: 10.1111/j.1532-950X.2011.00916.x. Epub 2011 Dec 20. PMID: 22188100.
6. Schmidli FE, Stein VM, Aikawa T, Boudrieau RJ, Jeandel A, Jeffery N, Jurina K, Moissonnier P, Rupp S, Vidondo B, Forterre F. Fractures of the Second Cervical Vertebra in 66 Dogs and 3 Cats: A Retrospective Study. Vet Comp Orthop Traumatol. 2019 May;32(3):200-206. doi: 10.1055/s-0039-1678542. Epub 2019 May 17. PMID: 31100766.
7. Shores A. Fractures and luxations of the vertebral column. Vet Clin North Am Small Anim Pract. 1992 Jan;22(1):171-80. doi: 10.1016/s0195-5616(92)50012-2. PMID: 1539424.
8. Sanders SG, Bagley RS, Silver GM, Moore M, Tucker RL. Outcomes and complications associated with ventral screws, pins, and polymethyl methacrylate for atlantoaxial instability in 12 dogs. J Am Anim Hosp Assoc. 2004 May-Jun;40(3):204-10. doi: 10.5326/0400204. PMID: 15131100.
9. Solitro GF, Welborn MC, Mehta AI, Amirouche F. How to Optimize Pedicle Screw Parameters for the Thoracic Spine? A Biomechanical and Finite Element Method Study. Global Spine J. 2024 Jan;14(1):187-194. doi: 10.1177/21925682221099470. Epub 2022 May 2. PMID: 35499547; PMCID: PMC10676166.
10. Matsukawa K, Konomi T, Matsubayashi K, Yamane J, Yato Y. Influence of Pedicle Screw Insertion Depth on Posterior Lumbar Interbody Fusion: Radiological Significance of Deeper Screw Placement. Global Spine J. 2024 Mar;14(2):470-477. doi: 10.1177/21925682221110142. Epub 2022 Jun 17. PMID: 35713986; PMCID: PMC10802553.
11. Sturges BK, Kapatkin AS, Garcia TC, Anwer C, Fukuda S, Hitchens PL, Wisner T, Hayashi K, Stover SM. Biomechanical Comparison of Locking Compression Plate versus Positive Profile Pins and Polymethylmethacrylate for Stabilization of the Canine Lumbar Vertebrae. Vet Surg. 2016 Apr;45(3):309-18. doi: 10.1111/vsu.12459. Epub 2016 Mar 23. PMID: 27007649.
12. Rink C, Christoforidis G, Abduljalil A, Kontzialis M, Bergdall V, Roy S, Khanna S, Slivka A, Knopp M, Sen CK. Minimally invasive neuroradiologic model of preclinical transient middle cerebral artery occlusion in canines. Proc Natl Acad Sci U S A. 2008 Sep 16;105(37):14100-5. doi: 10.1073/pnas.0806678105. Epub 2008 Sep 8. PMID: 18779582; PMCID: PMC2544585.

13. Agarwala A, Bucklen B, Muzumdar A, Moldavsky M, Khalil S. Do facet screws provide the required stability in lumbar fixation? A biomechanical comparison of the Boucher technique and pedicular fixation in primary and circumferential fusions. Clin Biomech (Bristol). 2012 Jan;27(1):64-70. doi: 10.1016/j.clinbiomech.2011.07.007. Epub 2011 Aug 16. PMID: 21849224.
14. Snead OM, Law AY, MacRae MR, Yoder HR, Kraus KH. Case Report: Use of veterinary cuttable plates to maintain reduction and reinforce polymethylmethacrylate (PMMA) fixation in two canine C2 vertebral fractures. Front Vet Sci. 2025 Apr 30;12:1534966. doi: 10.3389/fvets.2025.1534966. PMID: 40370826; PMCID: PMC12075552.