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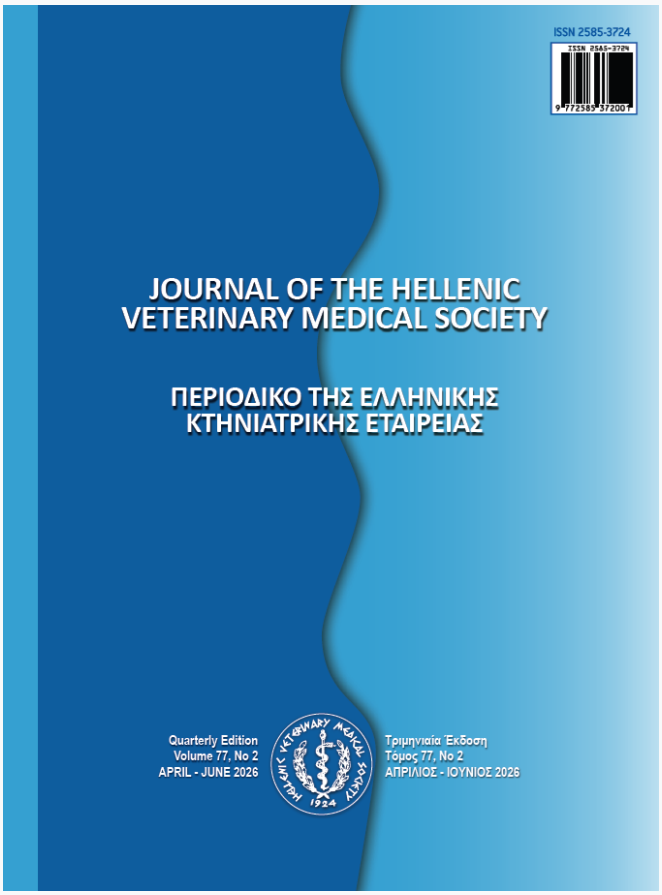

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The role of fenestration in the management of canine thoracolumbar intervertebral disc disease

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ABSTRACT: Intervertebral disc fenestration is a surgical procedure performed in neurosurgery for several decades, specifically in management of Thoracolumbar Intervertebral Disc Herniation (TIVDH). During this procedure a window is created in the annulus fibrosus and evacuation of the nucleus pulposus is attempted in order to eliminate the possibility of degenerative material extrusion into the spinal canal. This is a process which mainly occurs in chondrodystrophoid dog breeds that suffer from Hansen Type I Intervertebral Disc Disease. The idea of fenestration initially appealed to many surgeons and it was even used as monotherapy in TIVDH patients. However, the development of diagnostic imaging demonstrated the need for a more substantial decompressive intervention (e.g., hemilaminectomy or mini-hemilaminectomy) at the exact site of disc herniation, especially in severe cases with significant neurological deficits. One of the most challenging issues in the management of TIVDH is not only the effectiveness of the initial surgical or conservative treatment, but also the prevention of early and late recurrence episodes. The role of prophylactic fenestration remains a very controversial issue among specialists today. Many of them support the view that, in combination with decompressive surgery, the extruded disc and/or the immediately adjacent or even more distant discs should be fenestrated to avoid future extrusions and clinical relapses. A number of authors have conducted studies in order to assess follow up outcomes and clinical parameters after surgical decompression with or without fenestration. The goal was to determine whether or not fenestration can be considered as valid preventive measure. It is difficult however, to objectively evaluate these data due to variability among patients (breed, sex, age, neurological stage), differences in surgical techniques performed and limited follow-up periods. Older data suggested that recurrence rate was lower after fenestration of degenerative discs. Today, taking into account the results of more robust studies and meta-analyses, the fact that prophylactic fenestration reduces the rate of recurrences is strongly questioned. Possible postsurgical complications after fenestration are either iatrogenic or associated with spinal instability caused by alterations of supportive structures. Nevertheless, the frequency of such complications seems to be low in clinical practice.

Keyword: Prophylactic fenestration; canine thoracolumbar intervertebral disc disease; intervertebral disc fenestration

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INTRODUCTION

Intervertebral discs are supportive and protective structures of the spine that ensure mobility and load distribution.(Hansen, 1952) They consist of three main parts: the outer annulus fibrosus, the cartilaginous end plates and the inner nucleus pulposus.(Hansen, 1952) Under normal conditions degenerative changes occur with aging, causing a decrease in water content and proteoglycans (GAG) concentration of the disc nucleus. Nevertheless, in some breeds, referred to as chondrodystrophoid, such degenerative alterations take place at an early age, facilitating acute extrusion of nuclear material into the spinal canal.(Hansen, 1952) This process is described as chondroid metaplasia and it is commonly classified as Hansen Type I Thoracolumbar Intervertebral Disc Disease (TIVDD).(Smolders *et al.*, 2013; Fenn and Olby, 2020) According to the published literature, the most commonly affected dogs are Daschounds which are overrepresented at a younger age in comparison to other chondrodystrophoid breeds. It has also been found that the early extruded discs are characterized by marked degeneration and mineralization in Daschounds. (Funkquist, 1978; Davies and Sharp, 1983; Brisson *et al.*, 2004; Mayhew *et al.*, 2004; Ruddle *et al.*, 2006; Forterre *et al.*, 2008; Brisson, 2015b; Immekeppel *et al.*, 2021) It has been widely studied and demonstrated that the most vulnerable discs are those located at the thoracolumbar intervertebral spaces from T12-T13 to L2-L3.(Tanaka, Nakayama and Takase, 2004; Ruddle *et al.*, 2006)

Hansen Type II TIVDD refers to so-called fibroid metaplasia, which occurs mainly in non-chondrodystrophoid breeds, resulting in disc protrusion without extrusion of nuclear material.(Fenn and Olby, 2020) Back pain, paresis, or even paralysis, with or without urinary and fecal retention are common neurological signs of severe spinal cord compression caused by an acute thoracolumbar disc herniation episode. A long-term consequence on spinal cord function following peracute extrusion episodes is myelomalacia. (Griffiths, 1972)

There has been considerable debate among neurosurgeons for years regarding TIVDD management, as controversies persist between surgical approaches and conservative treatment options.(Griffiths, 1972; Funkquist, 1978; Gambardella, 1980; Davies and Sharp, 1983; Ruddle *et al.*, 2006; Forterre *et al.*, 2008; Brisson, 2015a; Forterre and Fingeroth, 2015; Moore, Early and Hettlich, 2016; Immekeppel *et al.*, 2021; Kerr, Crawford and De Decker, 2021) Additionally, there is ongoing disagreement regarding prophylactic procedures such as disc fenestration in TIVDD management due to conflicting study results.

Reviewing the historical background of the topic, intervertebral disc fenestration was first introduced in veterinary medicine in 1951, when it was suggested by Olsson (1951) as a method to treat and protect discs from recurrent herniation. (Olsson, 1951) Fenestration (derived from the word "fenestra") involves the creation of a penetrating window through the annulus fibrosus of the disc. Its purpose is to provide access to the nuclear content and mechanically remove it, ensuring that no material remains available to extrude into the spinal canal.(Brisson, 2015b) Since then, fenestration has gained popularity in veterinary medicine and many surgeons have widely performed it both as prophylactic and also as a therapeutic method. (Denny H. R., 1978; Funkquist, 1978; Butterworth and Denny, 1991)

In the past, it was believed that successful outcomes of fenestration were dependent on the surgeon's skill and the surgical technique, particularly the ability to remove as much nucleus pulposus material as possible.(Shores *et al.*, 1985) Prophylactic fenestration (PF) has been presented in numerous studies with initially encouraging results regarding its effectiveness. (Butterworth and Denny, 1991; Sterna, Sterna and Burzykowski, 2007; Forterre *et al.*, 2008; Sterna and Burzykowski, 2008; Brisson *et al.*, 2011; Aikawa *et al.*, 2012; Brisson, 2015a)

This paper aims to review the role of fenestration in the management of canine IVDD. It examines the indications, surgical techniques, prophylactic applications, outcomes, and potential complications associated with this procedure. Special attention is given to recurrence rates, differences between breeds, and current evidence supporting or questioning prophylactic fenestration in clinical practice.

SEARCH METHODOLOGY

For this review, relevant literature was identified through comprehensive searches of Google Scholar and PubMed databases. The searches were conducted using the following keywords: "prophylactic fenestration", "canine thoracolumbar intervertebral disc disease", and "intervertebral disc fenestration". Studies published in English without date restric-

tions were considered. Articles were screened for relevance to the topic, including original research, clinical trials, retrospective studies, and reviews that provided information on surgical techniques, outcomes, recurrence rates, and complications associated with prophylactic disc fenestration in dogs. Relevant data were extracted and synthesized to provide a comprehensive overview of current evidence and clinical practice.

FENESTRATION TECHNIQUES

First of all, fenestration is described as a manual technique, using a No. 11 scalpel. The creation of a rectangular window of four angles equidistant from each endplate and with a width not exceeding half of the vertebral body, is a simple way to clear the disc of degenerative nuclear material that might extrude in the future. The scalpel's cutting edge must be used with caution and directed away from the spinal cord, vascular structures and spinal nerves. The outlined piece of annulus is removed using mosquito forceps or rongeurs whereas the nuclear content is evacuated using dental-type instruments such as spatulas and curettes.(Brisson, 2017)

Another technique, power-assisted fenestration, is accomplished using a high-speed drill and burr and is performed in a similar manner to the manual technique, with the exception that an electric or pneumatic drill is used to create the fenestration window in the annulus fibrosus.(Holmberg *et al.*, 1990; Brisson, 2017) To achieve this, after opening the window with the drill, repetitive circular curettage is required to ensure integrity and safety of the spinal canal. In a cadaveric study, fenestration technique in thoracolumbar intervertebral discs were compared, and according to findings, the power assisted technique achieved superior nucleus evacuation, reaching up to 65%, while the manual technique did not exceed 40%.(Holmberg *et al.*, 1990)

In the following years, several innovative fenestration techniques were introduced. (Miyabayashi *et al.*, 1992; Dickey *et al.*, 1996; Forterre *et al.*, 2011; Thomovsky *et al.*, 2012; Dugat, Bartels and Payton, 2016) CUSA ultrasonic aspiration (Cavitron Ultrasonic Surgical Aspiration) is a surgical technique originating from soft tissue surgery and neurosurgery, used to resect tumors while minimizing damage to the surrounding healthy tissues. The CUSA Excel system consists of a console, two handpieces and specific disposable tips. It has been demonstrated to be a safe and effective method for removing a large proportion of the degenerative nuclear material. Nucleus evacuation is achieved through simultaneous ultrasonic vibrations and material ablation by the surgical tip. The device functiones selectively, allowing the removal of tissues with low water content. (Forterre *et al.*, 2011)

A vacuum-assisted tissue resection device (VRD) is a tool used in human neurosurgery and soft tissue excision, particularly for tumors. Its function is based on electric and nitrogen power and consists of a cutting component (two 360◦ rotating cannulas) and a foot-pedal regulated suction system. Suction is powered by nitrogen gas. A prospective cadaveric study assessed the remaining nuclear volume after VRD fenestration compared with manual fenestration. The results favored the vacuum-assisted technique, as it offered a safer and more cost-effective solution, achieving results comparable to manual fenestration.(Thomovsky *et al.*, 2012)

A less invasive method, proposed as an alternative to manual or power-assisted intervertebral disc fenestration, is so-called "Chemonucleolysis". It is based on the use of two proteolytic enzymes, chymopapain and collagenase.(Miyabayashi *et al.*, 1992) Despite disadvantages related to the availability of fluoroscopy, enzymes accessibility and possible postoperative disc alterations, chemonucleolysis is considered a technique with promising therapeutic potential. Reduced surgical time, lower postoperative care requirements and favorable results in mineralized discs are among the arguments supporting its use.

Percutaneous laser disc ablation (PLDA) is considered one of the most effective prophylactic methods against intervertebral disc herniation in both humans and animals.(Dickey *et al.*, 1996; Dugat, Bartels and Payton, 2016; Jeffery and Freeman, 2018) The procedure involves the passage of a fiberoptic cable through spinal needles, accurately targeting the center of the disc from T10-T11 to L4-L5. Fluoroscopic guidance is required and radiographs should be obtained in lateral and ventrodorsal projections. The laser remains activated for approximately 40 seconds, resulting in evacuation of nuclear material through vaporization or thermal ablation.(Jeffery and Freeman, 2018) The higher water content of a disc, the greater absorption of the laser wavelength and, consequently, the more effective the nuclear evacuation. Recurrence studies to date suggest that PLDA

warrants further investigation and development, particularly in young, non-chondrodystrophic dogs with no signs of nucleus pulposus degeneration. For example, in a recent report of 303 dogs undergoing PDLA, only 11 animals (3,6%) exhibited recurrence episodes confirmed by magnetic resonance imaging.(Dugat, Bartels and Payton, 2016) However, the reported recurrence rate in this study is questionable, as 60 dogs with suspected or confirmed herniation episodes following PLDA were also reported, increasing the recurrence rate to 19.8%. In another more recent study, the recurrence rate in dogs undergoing the same procedure was 6,7% (2/30).(Irizarry *et al.*, 2022) Nevertheless, the protection of spinal cord from this technique remains uncertain, as it is not definitively established that annular rupture cannot occur when PLDA is performed shortly after a herniation episode. Some authors suggest that a minimum period of six weeks is required for annular healing following an intervertebral disc herniation.(Jeffery and Freeman, 2018) It is generally accepted, based on moderate level evidence, that PLDA is relatively safe and less invasive than traditional fenestration techniques for achieving nuclear ablation, although none of the currently available methods fully satisfied this expectation.(Olby *et al.*, 2022)

APPROACHES FOR THORACOLUMBAR DISC FENESTRATION

The fenestration approach is chosen based on which intervertebral spaces require intervention and whether decompressive surgery is performed concomitantly or not (e.g., hemilaminectomy or mini hemilaminectomy).(Hansen, 1952) Several surgical approaches have been described for thoracolumbar disc fenestration, including ventral, dorsal, dorsolateral, ventrolateral and lateral approach.(Bojrab and Constantinescu, 1998) The ventrolateral and ventral approaches have largely been abandoned in clinical practice because of their increased invasiveness and the risk of injury to critical nerves and muscles.(Hansen, 1952; Bojrab and Constantinescu, 1998) In particular, the ventral approach requires thoracotomy or laparotomy to gain access to the disc, while simultaneous decompressive surgery cannot be performed.(Bojrab and Constantinescu, 1998)

During the dorsal approach, retraction of the multifidus and longissimus muscles, together with the lateral wall of vertebra, provides the surgeon with a limited operative field for fenestration and disc access. In addition, most of the remaining nuclear material, apart from the extruded portion, is located in the contralateral side of the disc relative to the dorsal fenestration site.(Morelius *et al.*, 2007; Smolders *et al.*, 2013)

Currently, many surgeons manage intervertebral disc herniation using decompressive surgery in combination with fenestration via dorsolateral or lateral approaches.(Brisson *et al.*, 2004, 2011; Aikawa *et al.*, 2012; Jeffery and Freeman, 2018) In a relevant study, the effects of dorsal, dorsolateral and lateral approaches were compared based on the amount of nucleus pulposus remaining within the disc following thoracolumbar disc fenestration in 20 beagle cadavers.(Morelius *et al.*, 2007) The findings indicated that, although the dorsolateral approach offers a wider surgical field and safer manipulations, this does not necessarily translate into more effective fenestration. Conversely, the lateral approach resulted in a significantly lower proportion of residual nuclear material compared with the other techniques. This is attributed to the adequate working depth provided by the transverse angle, allows the vertebral bodies to be approached horizontally, requiring minimal space to access the nucleus pulposus. Easier bone detachment and minor muscle trauma are additional advantages of the lateral approach.(Hansen, 1952; Yturraspe *et al.*, 1973; Butterworth and Denny, 1991; Moissonnier, Meheust and Carozzo, 2004) Nevertheless, it should not be overlooked that the dorsolateral approach provides the surgeon with the ability to perform concomitant hemilaminectomy or pediculectomy more easily, in contrast to the lateral approach.(Morelius *et al.*, 2007; Olby *et al.*, 2022)

FENESTRATION AS THERAPY FOR THORACOLUMBAR INTERVERTEBRAL DISC DISEASE

Initially, the concept of fenestration arose from the belief that reducing pressure in the epidural space would result from removing its dynamic causative factor, thereby achieving spinal decompression.(Olsson, 1951; Butterworth and Denny, 1991) From the time fenestration was first described until the 1990s, it was widely preferred as monotherapy for dogs with IVDH, with encouraging success rates documented regardless of the severity of their neurolog-

ical deficits.(Denny H. R., 1978; Funkquist, 1978; Butterworth and Denny, 1991)

In dogs presenting with relatively mild symptoms, ranging from back or neck pain to paraplegia with preserved deep pain perception, treatment with fenestration alone, performed at multiple intervertebral discs including the affected one, showed high recovery rates.(Denny H. R., 1978; Butterworth and Denny, 1991; Moore *et al.*, 2020) However, there is no evidence demonstrating that fenestration as a sole therapy produces superior outcomes compared with conservative treatment. Conversely, dogs with absent deep pain perception exhibited lower recovery rates, as low as 30%, when treated with fenestration alone,(Butterworth and Denny, 1991) compared with typically reported recovery rates of 53–68% in similar cases treated by hemilaminectomy, with or without prophylactic fenestration.(Olby *et al.*, 2003; Langerhuus and Miles, 2017; Moore *et al.*, 2020)

Published reports on fenestration as monotherapy in dogs with neurological deficits are scarce. A recent review examining the outcomes of partial percutaneous discectomy without decompressive surgery in 331 dogs with thoracolumbar disc protrusion demonstrated recovery in only 38% of cases, supporting the notion that dogs with severe neurological deficits and absent deep pain perception (i.e., grades 3–5) primarily rely on decompressive surgery for recovery.(Kinzel *et al.*, 2005)

Cross-sectional imaging has enabled detailed visualization of processes occurring in the epidural space after disc extrusion, leading to the conclusion that severe spinal cord compression and deformation frequently occur.(Ito *et al.*, 2005) For this reason, most neurosurgeons have abandoned fenestration as an exclusive surgical treatment for IVDH, at least without simultaneous decompressive surgery..(Brisson, 2015a; Freeman and Jeffery, 2017, 2022) Currently, the most widely supported decompressive procedure is hemilaminectomy, with or without removal of the articular processes.(Hall and Freeman, 2021)

PROPHYLACTIC ROLE OF THORACOLUMBAR INTERVERTEBRAL DISC FENESTRATION

In recent years, one of the most debated topics regarding fenestration has been its prophylactic role, not only for the herniated disc but also for adjacent or more cranial and caudal discs.(Hall and Freeman, 2021) Recurrence incidents are defined variably, depending on the time of presentation, dog breed, and clinical presentation, which complicates the interpretation of statistical outcomes. Consequently, recurrence is not consistently evaluated in studies assessing the protective effects of fenestration. Short or incomplete follow-up further limits accurate assessment, as recurrences are classified as early or late, typically occurring up to 36 months postoperatively (mean 8–14 months) (Brisson *et al.*, 2004, 2011; Brisson, 2015b) Early recurrence usually occurs 4–6 weeks after surgery and is considered to occur at the initial herniation site, whereas late recurrence generally arises in adjacent discs.(Mayhew *et al.*, 2004; Forterre *et al.*, 2008; Aikawa *et al.*, 2012)

A recent study correlated degenerative findings on MRI at the time of the first surgery with the likelihood of recurrence and found that most late recurrences did not occur in discs adjacent to the previously protruded or fenestrated disc.(Longo *et al.*, 2021) The authors recommended performing fenestration in cases with multiple discs showing clear signs of complete degeneration in the thoracolumbar region, excluding the currently affected disc. In all cases, a thorough assessment of disc imaging characteristics is essential, as mineralization is widely regarded as indicative of increased herniation risk. (Brisson *et al.*, 2004; Forterre *et al.*, 2008; Brisson, 2015a) It is also important to distinguish discs showing only nuclear mineralization without space narrowing from those with generalized mineralization and intravertebral space collapse, as the latter, though more common, are considered low-risk for extrusion.(Brisson, 2015a) A common challenge remains: discs that appear normal at present may degenerate over time, as demonstrated on follow-up MRI.(Jeffery *et al.*, 2018)

In 2004, a retrospective study of 252 surgically treated dogs performed single or multiple prophylactic fenestrations in addition to spinal decompression. Recurrence was reported in 12/252 dogs (4.8%). Single fenestration at the decompression site was performed in 37 dogs (14.7%), with 2/37 (5.4%) developing extrusion at a different disc space.(Brisson *et al.*, 2004)

In 2011, the same author conducted a randomized clinical trial with 207 dogs, comparing single-site

versus multi-site fenestration.(Brisson *et al.*, 2011) Reliable follow-up was available for 189 cases. In the multi-site group, the recurrence rate was 7.45%, whereas the single-site group experienced approximately 18% recurrence. Notably, 91.7% of all prolapses occurred at disc spaces that were neither exclusively fenestrated nor included in prophylactic treatment. Other studies also confirm the beneficial effect of fenestration. In one study of 662 surgically managed dogs with thoracolumbar IVDD, hemilaminectomy and fenestration were performed.(Aikawa *et al.*, 2012) After one year, only 15 cases (2.26%) required a second surgery due to reherniation, and the authors noted that the risk of a second extrusion increases 26.2-fold when fenestration is omitted during decompression. Nevertheless, 66 dogs with clinical signs of potential relapse were successfully managed conservatively, which could adjust the reported recurrence rate from 2.26% to 12%.

A recent medical record study included 84 French Bulldogs with cervical (29/84) and thoracolumbar (55/84) IVDH who had previously undergone successful decompressive surgery. In TL IVDH cases, 33/55 dogs underwent fenestration only at the affected disc, while 22/55 underwent fenestration at the immediately adjacent discs, caudally and cranially. Extensive fenestration was avoided due to breed-specific anatomical limitations. Follow-up via MRI or neurological examination demonstrated that 29/ 55 dogs treated with decompressive surgery in conjunction with disc fenestration, experienced recurrence.(Kerr, Crawford and De Decker, 2021) This recurrence ratio (53%) is higher comparing to those presented in previous studies.(Mayhew *et al.*, 2004; Forterre *et al.*, 2008; Brisson *et al.*, 2011; Aikawa *et al.*, 2012) Limitations included restricted follow-up, underdiagnosis by owners or veterinarians, lack of re-screening, and potential euthanasia after a second IVDH episode.(Butterworth and Denny, 1991; Aikawa *et al.*, 2012)

Until recently, prophylactic fenestration in addition to appropriate decompression was generally believed to reduce recurrence risk.(Mayhew *et al.*, 2004; Forterre *et al.*, 2008; Freeman and Jeffery, 2017) However, literature indicates that second IVDH episodes in the thoracolumbar spine occur at approximately 2%, and in studies incorporating fenestration, the rate was sometimes higher.(Mayhew *et al.*, 2004; Forterre *et al.*, 2008; Brisson, 2010; Aikawa *et al.*, 2012)

A recent systematic review and meta-analysis evaluated recurrence in dogs treated with decompression with or without prophylactic fenestration (PF). .(Pontikaki *et al.*, 2022) Among 5,457 dogs, PF was performed in 1,264 cases, with 504 dogs (~9%) experiencing at least one confirmed or suspected recurrence, including 164/1,264 (~13%) in the PF group. Daschunds accounted for the majority of total recurrences (20.83%). In the PF group, 82/164 recurrences occurred in discs distant from the fenestrated area (50%), while only 8/164 (4.88%) occurred in the surgically treated region. Moreover, 6/164 relapses occurred cranial to the initially treated disc (3.66%), further complicating the assessment of PF efficacy

The meta-analysis (Pontikaki *et al.*, 2022) also compared recurrence rates between PF and non-PF groups. Reherniation occurred in 59/1,406 dogs (4.2%), of which 43 dogs (72.9% of total recurrences) had received prophylactic fenestration. This review included all historical studies of fenestration to assess its effect in managing thoracolumbar IVDH. However, drawing firm conclusions is difficult due to factors such as breed differences, inconsistent reporting, and variability in which discs were fenestrated. Additional clinical trials are needed to clarify the true benefit of PF.

A recent survey of 190 board-certified neurologists and 133 surgeons explored opinions on performing PF alongside decompressive surgery. (Hall and Freeman, 2021) Most neurologists (82%) supported concurrent fenestration, whereas the approval among surgeons was lower (55%). Recent studies suggest that recurrence rates after disc fenestration may be higher than previously reported.(Aikawa *et al.*, 2012; Kerr, Crawford and De Decker, 2021; Pontikaki *et al.*, 2022) When considering adjacent or more distant discs, especially those showing degenerative changes on imaging, decisions about fenestration should take into account the dog's overall clinical condition, expected surgery duration, and breed-specific risks (e.g., Daschunds, French Bulldogs). (Jeffery *et al.*, 2018; Olby *et al.*, 2022)

IMPLICATIONS OF FENESTRATION ON BIOMECHANICS OF THE SPINE

The role of intervertebral discs, together with other musculoskeletal structures (e.g., facet joints), is undoubtedly critical for maintaining vertebral col-

umn stability. Numerous studies have evaluated the outcomes of fenestration, taking into account factors such as transposition angles and histological changes.(Fauber *et al.*, 2006; Moissonnier *et al.*, 2014; Grunert *et al.*, 2017)

A detailed analysis was conducted in a recent in vivo study investigating structural and histological degenerative alterations in canine spines following procedures such as discectomy and fenestration. Observed morphological changes in vertebral bodies adjacent to the operated discs included a 24% reduction in foraminal height over 16 weeks, sclerotic endplates (with increased radiopacity compared to the adjacent control group) and ventral spondylosis of the cranial vertebral body. Imaging performed four months postoperatively demonstrated complete collapse of the discectomized discs, indicative of end-stage degeneration. Histologically, degenerative changes were also evident. These included sectional rupture of the annulus fibrosus, cellular metaplasia of annular tissue from fibroblasts to chondrocytes and thinning of both cartilaginous endplates.(Grunert *et al.*, 2017)

Surgical intervention in these structures, particularly in the intervertebral discs through procedures such as fenestration, negatively affects the stability of the entire spine.(Schulz *et al.*, 1996; Hill, Lubbe and Guthrie, 2000; Brisson *et al.*, 2004; Arthurs, 2009; Aikawa *et al.*, 2012)

POSTSURGICAL COMPLICATIONS

Several postoperative complications may occur after fenestration largely depending on the technique employed, the surgeon's skill and familiarity with the procedure, and the duration of surgery. First, particular caution is required to prevent nuclear material from entering the spinal canal during manipulations immediately following fenestration. This iatrogenic complication has been reported in the literature,. (Brisson *et al.*, 2011; Harris and Freeman, 2020) with one study documenting an occurrence rate of 33.4% (7/21 cases).(Harris and Freeman, 2020)

Additionally, injury to nerves or blood vessels has been described (e.g., spinal or peripheral nerves, arteries, and other structures adjacent to the surgical field).(Brisson *et al.*, 2011; Aikawa *et al.*, 2012) Fenestration in the lumbar region (caudal to L3) carries a particularly high risk of spinal nerve trauma, and therefore fenestration in areas more caudal to L3 is currently not recommended.(Moore *et al.*, 2020) Paresis, as well as urinary or fecal incontinence, are commonly observed consequences of nerve injury..(Bartels, Creed and Yturraspe, 1983) In some thoracolumbar cases, these injuries may be initially subtle, but long-term effects can include multifidus muscle atrophy or laxity of the abdominal wall. (Brisson, 2015a)

When operating in the caudal thoracic region, extreme caution is necessary, as major vessels and the thoracic wall (including the caudal vena cava and aorta) surround the surgical field. Improper handling or aggressive manipulation of instruments may lead to pneumothorax, hemothorax, severe hemorrhage, or even death.(Brisson *et al.*, 2004; Brisson, 2015a; Pontikaki *et al.*, 2022)

Fenestration increases both surgical and anesthesia time compared with decompressive surgery alone. Prolonged procedures elevate anesthetic risk in unstable dogs, as decreases in blood pressure, heart rate, and spinal cord perfusion during anesthesia may worsen the patient's condition and the surgical outcome.(Dixon and Fauber, 2017; Fenn *et al.*, 2017) Additionally, increased trauma to surrounding soft tissues predisposes to infection and additional morbidity.(Brisson, 2015b)

Discospondylitis is another potential complication and is among the most frequently reported, followed by neurological deterioration, pneumothorax, hematomas at PLDA needle sites, ataxia, and abdominal wall weakness.(Sterna and Burzykowski, 2008; Immekeppel *et al.*, 2021; Pontikaki *et al.*, 2022) Regarding PLDA, contamination and abscess formation have also been documented.(Fenn and Olby, 2020)

Overall, the incidence of postsurgical complications has been reported as very low, approximately 0.01% (15/1500 cases), regardless of the technique used.(Moore *et al.*, 2020) Nevertheless, further in vitro and clinical studies are needed to provide a more reliable assessment of the impact of fenestration.

CONCLUSION

The protective role of disc fenestration is a topic that continues to provoke debate among veterinarians. Spinal cord decompression, combined with prophylactic fenestration of the affected disc, is generally considered an effective approach in the management of IVDH. On the other hand, prophylactic fenestration of thoracolumbar (TL) IVDH is associated

with high recurrence rates, which has led to ongoing controversy.

Nevertheless, despite positive outcomes reported in numerous studies, more recent data have produced contradictory findings. Unfortunately, there remain significant gaps in our understanding of fenestration's efficacy, and further research is necessary to determine whether this technique can be considered reliable, given the currently inconclusive evidence.

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