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Influence of Breed and Body Conformation on Vertebral Implant Insert Angles in Dogs

Lina Nowak[1] N. Grapes[2] S. De Decker[3]

[1] The IVC Evidensia Referral Hospital, Helsingborg, Sweden
[2] Davies Veterinary Specialists, Hertfordshire, United Kingdom
[3] Department of Clinical Science and Services, The Royal Veterinary College, University of London, Hatfield, United Kingdom

Address for correspondence Lina Nowak, DVM, The IVC Evidensia Referral Hospital, 25466 Helsingborg, Sweden (e-mail: lina.nowak@evidensia.se).

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Abstract

Objective To evaluate the effect of breed and body conformation on the vertebral insertion corridor angles for stabilizing spinal surgery in dogs.

Study Design Computed tomography studies of the vertebral column of 100 dogs from 10 representatives of 10 FCI (Fédération Cynologique Internationale) breed groups were randomly and blindly evaluated for vertebral insertion corridor angles. Insertion angles were measured for the last six cervical vertebrae (C2–C7), the last four thoracic vertebrae (T10–T13), the seven lumbar vertebrae (L1–L7), and the sacrum (S1).

Results Insertion angle was significantly influenced by breed at C6 ($p = 0.001$), C7 ($p = 0.008$), T13 ($p = 0.032$), L6 ($p = 0.011$), and S1 ($p = 0.009$). At C6, Pugs had significantly larger mean insertion angles (MIAs) compared with Beagles ($p = 0.016$), Miniature Dachshunds ($p = 0.024$), Greyhounds ($p = 0.004$), and West Highland White Terriers ($p = 0.001$). English Springer Spaniels had significantly smaller MIA at C7 compared with Siberian Huskies ($p = 0.037$) and Pugs ($p = 0.033$). German Shepherds had significantly smaller MIA at L6 compared with Beagles ($p = 0.044$), Miniature Schnauzers ($p = 0.029$), and English Springer Spaniels ($p = 0.047$). Miniature Dachshunds had significantly larger MIA at S1 compared with Beagles ($p = 0.009$), Pugs ($p = 0.015$), Miniature Schnauzers ($p = 0.010$), and English Springer Spaniels ($p = 0.006$).

Conclusion Breed and body conformation are important factors when planning instrumented spinal surgery in dogs. Individualized planning for spinal instrumentation seems to be critical.

Keywords
- dog
- insertion angles
- spinal surgery
- spinal fractures
- luxations

Introduction

Spinal stabilization is indicated in a variety of canine spinal instability disorders including spinal fractures, luxations, and vertebral malformations. Surgical treatment is aimed at realigning and stabilizing the affected vertebrae, discs, and zygapophyseal joints with or without spinal cord decompression.[1–6]

Although multiple surgical techniques for vertebral stabilization have been described, most involve the placement of screws or pins in multiple vertebral bodies.[7–9] While these surgical techniques provide rigid intervertebral fixation, they are associated with a risk of complication. Good knowledge of three-dimensional (3D) anatomy, diagnostic imaging, and advanced surgical skills are required to reduce the risks of iatrogenic injury to the vasculature, nerve roots, and spinal cord.[4–6,10–13] Other potential surgical complications include screws pulling out or technical failures such as pins breaching the cortex of the pedicles.[13,14]

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Table 1 FCI groups and the selected representative breed from each group

FCI group no.	FCI group name	Selected representative breed
1	Sheepdogs and cattle dogs	German Shepherds
2	Pinschers and Schnauzers	Miniature Schnauzers
3	Terriers	West Highland White Terriers
4	Dachshunds	Miniature Dachshunds
5	Spitz and primitive types	Siberian Huskies
6	Scent hounds and related breeds	Beagles
7	Pointing dogs	German Wirehaired Pointers
8	Retrievers, flushing dogs, water dogs	English Springer Spaniels
9	Companion and toy dogs	Pugs
10	Sighthounds	Greyhound

Abbreviation: FCI, Fédération Cynologique Internationale.

Recent studies have evaluated safe implant insertion corridors describing entry points, exit points, and insertion corridor angles in detail.[10,13–17] These studies have demonstrated differences between anatomical regions and species, for example, cat versus dog.[18] It is currently unknown if body conformation influences safe insertion corridors. Dogs come in a wide range of shapes and sizes. The large variability in dog breeds characterized by different body conformations might pose an additional technical challenge in vertebral fixation surgery.

The aim of this study was therefore to evaluate the angles of safe insertion corridors in dogs of different breeds and with different body conformations. It was hypothesized that ideal insertion corridors, with an emphasis on insertion angles, would be different in dogs with different body conformations.

Materials and Methods

Data Collection

This study used retrospectively collected data from previously performed computed tomography (CT) scans for a variety of clinical indications at the small animal referral hospital at the Royal Veterinary College between May 2018 and May 2022. The study was considered below the threshold for ethical approval.

For the aims of this study, the selection of cases was based on the characterization of dogs as claimed by the international world canine organization Fédération Cynologique Internationale (FCI; https://www.fci.be/en/). According to FCI, purebred dogs are arranged in 10 individual groups. In this study, we opted for one representative breed from each group and then 10 dogs from each chosen representative breed. One hundred adult dogs from 10 separate breeds were selected. Representative breeds were designated from each group. (►**Table 1**).

Dogs were included if the CT study included the cervical, thoracolumbar, and sacral vertebral column. In dogs with pathology that interfered with normal vertebral anatomy, such as fracture, luxation, previous spinal surgery, vertebral malformation, or diffuse idiopathic skeletal hyperostosis, measurements were solely performed on the unaffected vertebrae.

A 320-slice helical CT scanner was used in all cases (Aquilion ONE Genesis Edition, Canon Medical Systems, Otawara, Japan). The CT settings for image acquisition were helical mode, 1 to 2 mm slice thickness, −1 interval between slices, 140 kV, 120 mA, 110 mm acquisition field of view, bone, and soft tissue reconstruction algorithms, 512 × 512 matrix. After the axial CT study was completed, sagittal and coronal reconstructions were made.

All studies were anonymized and randomized with a random number generator (www.random.org). All measurements were performed by one author who was unaware of the signalment of each individual dog (L.N.). The DICOM (Digital Imaging and Communications in Medicine) files were transferred from a picture archiving system to a computer workstation (MacBook Air, 2022, Apple, United States) and imported into an imaging software program (Horos, v3.3.6, www.horosproject.org). The CT images were viewed in a bone window using multiplanar reconstructions. The angle was defined by using the angle measurement tool in the Horos toolbar. Insertion corridor angles were measured, according to Watine et al, for the last six cervical vertebrae (C2–C7), the last four thoracic vertebrae (T10–T13), the seven lumbar vertebrae (L1–L7), and the sacrum (S1).[16] Technical aspects of the measurements were based on the same study. A ventral surgical approach was chosen for cervical vertebrae and a dorsal approach was chosen for thoracic, lumbar, and sacral vertebrae.

The characteristic of the insertion angle, α, was the angle between the insertion corridor and the sagittal plane of the vertebra (►**Figs. 1–3**).

Statistical Analysis

The results were statistically analyzed using SPSS statistics 28 version 28.0.0.0 (IBM). Histograms were plotted of continuous variables (angle recorded for each vertebral body) to assess for normality of distribution. Normally distributed continuous data were analyzed with one-way analysis of

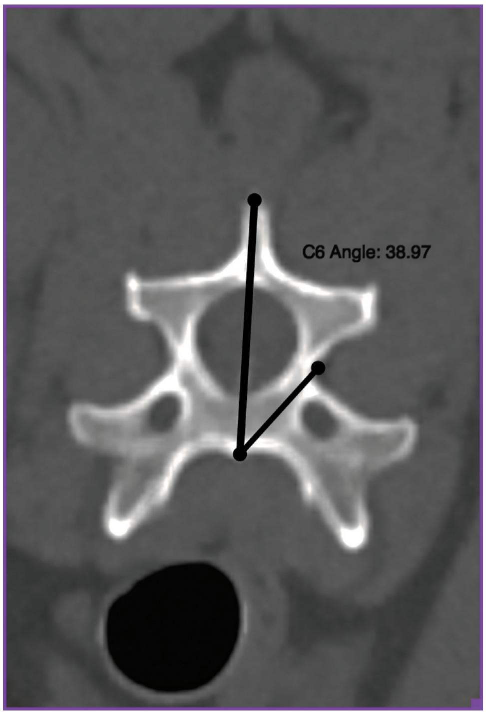

Fig. 1 Insertion angle measurement in vertebra C6 using the Horos angle measurement tool.

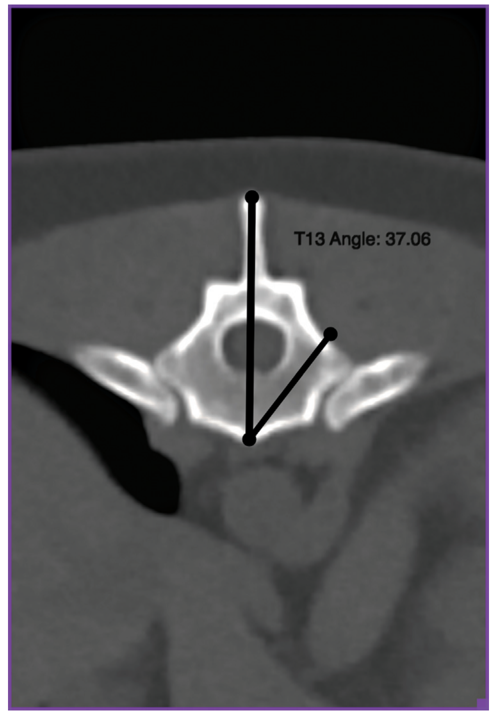

Fig. 3 Insertion angle measurement in vertebra T13 using the Horos angle measurement tool.

variance (ANOVA) and pairwise post-hoc Tukey testing. Nonnormally distributed data were analyzed with a Kruskal–Wallis test. Normally distributed data are presented with mean and standard deviation, while nonnormal continuous data are presented with median and range. A p-value of 0.05 was considered significant.

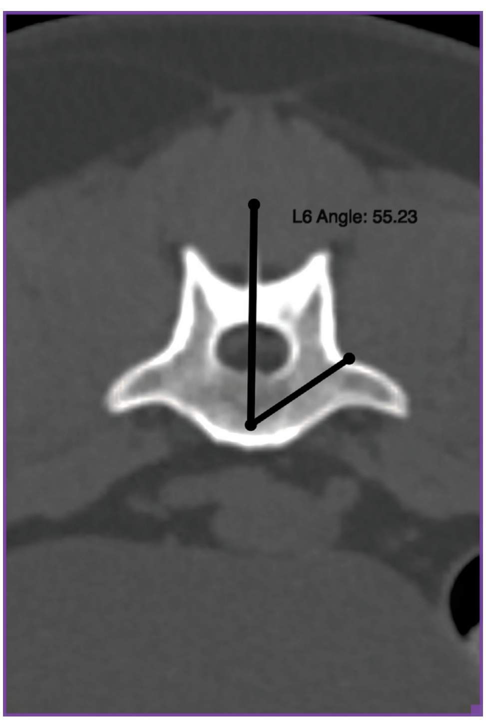

Fig. 2 Insertion angle measurement in vertebra L6 using the Horos angle measurement tool.

Results

Of the 100 dogs included in this study, 52 were males (36 neutered) and 48 were females (38 neutered), aged between 11 months and 14.6 years (median: 9.9 years). CT was performed for a variety of clinical indications, including metastatic screening ($n = 48$), brachycephalic obstructive airway syndrome ($n = 6$), immune-mediated hemolytic anemia ($n = 6$), pyrexia of unknown origin ($n = 6$), cerebrovascular accident ($n = 5$), trauma ($n = 4$), lymphadenopathy ($n = 4$), immune-mediated polyarthritis ($n = 4$), cardiac disease ($n = 4$), gastrointestinal disease ($n = 4$), hepatic disease ($n = 3$), diffuse neuromuscular disease ($n = 2$), pleural effusion ($n = 2$), pyothorax ($n = 1$), and Horner's syndrome ($n = 1$).

A summary of the obtained insertion angles for each breed can be found in ►**Tables 2–4**. There was a significant influence of breed on the insertion angle for C6 ($p = 0.001$), C7 ($p = 0.008$), T13 ($p = 0.032$), L6 ($p = 0.011$), and S1 ($p = 0.009$) vertebrae. Pairwise comparisons for C6 revealed that Pugs had significantly larger mean insertion angle (MIA) compared with Beagles ($p = 0.016$), Miniature Dachshunds ($p = 0.024$), Greyhounds ($p = 0.004$), and West Highland White Terriers (WHWTs; $p = 0.001$). At C7, English Springer Spaniels (ESS) had significantly smaller MIA compared with Siberian Huskies ($p = 0.037$) and Pugs ($p = 0.033$). Pairwise comparisons for T13 did not reveal any significant differences between individual breeds. At L6, German Shepherd dogs had significantly smaller MIA compared with Beagles ($p = 0.044$), Miniature Schnauzers ($p = 0.029$), and ESS ($p = 0.047$). At S1, Miniature Dachshunds had a significantly larger MIA compared with Beagles ($p = 0.009$), Pugs ($p = 0.015$), Miniature Schnauzers ($p = 0.010$), and ESS ($p = 0.006$). No significant difference

Table 2 Average insertion angle for each breed C2-C7

Breed and average angle	Angle C2	Angle C3	Angle C4	Angle C5	Angle C6	Angle C7
Beagle	46.56	40.65	43.35	44.87	49.14	56.13
Miniature Dachshund	50.05	38.49	43.02	46.22	49.23	53.82
German Shepherd	56.14	53.39	51.66	51.95	53.39	55.92
Greyhound	52.56	42.95	45.39	47.48	48.25	55.45
Siberian Husky	46.43	43.63	44.52	45.76	50.08	57.04
German Wirehaired Pointer	53.18	45.43	43.20	49.19	50.44	54.36
Pug	51.52	43.84	42.41	49.27	56.84	57.21
Miniature Schnauzer	50.54	47.04	49.29	49.93	50.45	56.72
English Springer Spaniel	46.33	48.61	40.88	48.59	51.20	52.64
West Highland White Terrier	54.18	45.86	48.54	45.71	47.12	54.20

Table 3 Average insertion angle for each breed T10-L2

Breed and average angle	Angle T10	Angle T11	Angle T12	Angle T13	Angle L1	Angle L2
Beagle	30.55	35.14	38.74	44.21	57.88	57.31
Miniature Dachshund	33.18	37.26	40.17	44.62	57.17	57.82
German Shepherd	30.00	32.87	36.89	39.29	56.25	57.76
Greyhound	33.17	38.80	40.36	45.55	57.35	57.77
Siberian Husky	33.71	37.06	42.58	43.61	56.70	57.46
Germain Wirehaired Pointer	31.05	34.67	38.23	42.45	54.92	55.56
Pug	30.26	32.96	37.95	39.74	56.85	57.66
Miniature Schnauzer	34.96	36.52	40.71	45.25	57.65	59.88
English Springer Spaniel	32.51	34.86	39.36	42.51	57.39	56.72
West Highland White Terrier	33.39	37.15	40.20	40.53	58.03	56.89

Table 4 Average insertion angle for each breed L3-S1

Breed and average angle	Angle L3	Angle L4	Angle L5	Angle L6	Angle L7	Angle S1
Beagle	57.76	58.86	55.27	53.54	3.41	4.54
Miniature Dachshund	57.36	58.11	53.89	50.99	3.72	8.17
German Shepherd	55.08	56.06	53.69	48.54	5.21	5.30
Greyhound	55.69	57.30	54.13	50.59	3.14	5.30
Siberian Husky	57.55	59.10	56.27	52.29	3.19	5.70
German Wirehaired Pointer	56.32	56.79	52.40	50.73	3.41	5.43
Pug	57.11	55.13	53.75	51.42	4.44	4.60
Miniature Schnauzer	59.54	57.09	55.24	53.76	3.73	4.57
English Springer Spaniel	57.72	56.21	54.84	53.51	8.67	4.45
West Highland White Terrier	58.20	57.67	54.87	53.74	4.11	5.07

was identified in the insertion angles at the remaining vertebral levels (►**Table 5** and **6**).

Discussion

This study evaluated the influence of breed and body conformation on the angle of an optimal anatomical trajectory in the transverse plane for spinal stabilizing surgery in 10 selected dog breeds of different body conformations. Although the obtained measurements agreed with previous studies, our results suggest that breed significantly influences the insertion angles of the C6, C7, T13, L6, and S1 vertebrae. In this study, the major differences were in Pugs at C6, ESS at C7, German Shepherds at L6, and Miniature Dachshunds at S1.

Table 5 Inclusion number, exclusion number, mean and median angle, standard deviation, min. and max. angle, *p*-value and method of statistical analysis for calculations of vertebrae C2 to T12

Vertebrae	C2	C3	C4	C5	C6	C7	T10	T11	T12
Included no.	23	41	73	95	98	99	98	98	98
Missing/excluded no.	77	59	27	5	2	1	2	2	2
Mean α	49.81	45.03	45.48	47.93	50.56	55.33	32.31	35.77	39.55
Median α	48.39	45.38	46.53	49.67	50.59	55.11	32.09	35.48	39.03
Std. deviation	4.05	7.67	7.59	6.56	5.09	3.16	4.14	4.69	4.54
Min α	41.66	31.85	30.36	33.8	31.46	47.37	23.18	24.01	30.05
Max α	56.14	58.16	59.26	59.23	64.22	62.04	41.43	46.04	48.95
p-Value	0.085	0.274	0.101	0.297	0.001	0.008	0.087	0.077	0.245
Method	KW	KW	A	KW	A	A	A	A	A

Table 6 Inclusion number, exclusion number, mean and median angle, standard deviation, min. and max. angle, *p*-value and method of statistical analysis for calculations of vertebrae T13 to S1

Vertebrae	T13	L1	L2	L3	L4	L5	L6	L7	S1
Included no.	97	98	97	97	97	97	96	95	98
Missing or excluded no.	3	2	3	3	3	3	4	5	2
Mean α	42.84	57.04	57.51	57.23	57.25	54.46	51.89	3.78	5.32
Median α	42.37	57.13	57.73	57.50	57.48	54.53	51.70	3.55	5.18
Std. deviation	5.05	3.06	3.28	3.69	3.24	2.89	3.64	1.86	2.28
Min α	33.68	49.32	48.16	46.01	50.41	46.32	40.63	0.61	0.96
Max α	56.04	63.87	64.43	65.90	64.54	62.93	61.65	12.81	14.06
p-Value	0.032	0.588	0.392	0.297	0.153	0.203	0.011	0.609	0.009
Method	A	A	A	A	A	A	A	KW	A

Although insertion angles have previously been determined for individual vertebral levels,[16] the results of this study suggest that body conformation can affect these angles. This limits the application of generalized insertion angles between breeds. It might therefore be ideal and even necessary to determine the ideal insertion corridor angle for each individual patient that requires instrumented spinal surgery. Presurgical planning of stabilizing spinal surgery requires diagnostic imaging to establish the optimal safe trajectory corridor. Imaging can be undertaken via survey radiographs, CT, or magnetic resonance imaging (MRI). Previous studies proved CT superior over radiographs and MRI in detecting vertebral osseous traumatic pathologies.[11,14,19,20]

The sensitivity of conventional radiography is generally considered moderate for fractures and subluxations and low for evaluating exact implant placement.[11,20] CT is more sensitive in identifying vertebral osseous pathologies and in assessing measurements considering surgery.[11] The possibility of 3D imaging allows measurements from all possible angles, valuable in surgical planning.[11,14]

A combination of CT and MRI is recommended in a complete assessment of vertebral trauma in dogs. MRI may be able to detect the presence of soft tissue injuries and fractured vertebrae but cannot replace CT for identifying precise fracture morphology and possible measurements for implant placement.[19,21]

All surgical techniques for spinal stabilization require accurate positioning of the stabilizing implants.[4,5,12,16] Although CT is the ideal technique to determine optimal trajectories, it can be challenging to reproduce these ideal trajectories in vivo during spinal surgery.[14] Correct vertebral implant placement requires correct assessment of vertebral conformation and anatomy, emerging nerve roots and surrounding vasculature, and soft tissue structures. The difficulty of replicating ideal intraoperative insertion angles is demonstrated by several studies, where considerable differences between theoretical measurements and free-hand implant placement were shown.[7,10,13,15,17]

More recent developments in veterinary medicine advocate the use of individualized and custom-made 3D drill guides.[3,10,22,23] This new technology facilitates more accurate and hence safer implant placement; however, it comes with an expense. In addition, 3D drill guides are not widely available and can be considered cost-prohibited for a subset of clients. And even if they reduce the risk of complications, most fractures/luxations are time critical and cannot be delayed for the printing of guides. For most veterinary surgeons, there will be situations where in vivo free-hand positioning inevitably is required. Apart from detailed knowledge about the specific type of vertebra and the mean angle of insertion for a safe trajectory, this study suggests adding breed and body conformation into individualized surgical planning. Although this study identified that especially Pugs at C6, ESS at C7, German Shepherds at L6, and Miniature Dachshunds at S1 had different insertion angles, more extensive studies are necessary to evaluate for potential differences between additional breeds.

The current study has several limitations. First, all measurements were performed by a single person. It can however be hypothesized that this could have contributed to the consistency of the measurements. However, using multiple reviewers could allow for testing measurement sensitivity. Second, only one representative breed was selected for each group of dogs. Although this approach was sufficient to demonstrate the influence of body conformation on insertion angles, it remains unclear if the obtained measurements of one breed can be extrapolated to other breeds within the same group. The FCI groups are large and heterogeneous with several breeds of different sizes and conformation within the same group. Identifying the ideal representative breed for one group is challenging. For example, in FCI group 8, retrievers, flushing dogs, and water dogs, where an ESS was chosen as a representative breed in this study, there are substantial differences from larger dogs such as Golden Retrievers or Labrador Retrievers. Even within the same breed, there can be considerably different phenotypes. In addition, some of the selected breeds, WHWTs, Pugs, and Beagles, carry several chondrodystrophic characteristics that might influence the vertebral conformation. These are all factors favoring an individualized approach. Considering the heterogenicity of the breeds within the FCI groups, the identified insertion angles of specific vertebrae should probably not be used as generalized corridor angles.

In addition, insertion corridor angles are merely one part of the presurgical planning. Additional aspects such as entrance points, exit points, and evaluation of implant positioning in the sagittal and coronal plane will likewise have an impact on the outcome. Moreover, the clinical relevance of smaller differences in insertion angles can be debated as these might be challenging to achieve surgically.

In conclusion, the results of this study suggest adding breed into the individualized surgical planning and underline that breed by itself is an important factor when managing spinal stabilizing surgery in dogs. Individual planning is critical but safe corridor angles of specific vertebrae, as presented in this study, can support the assessment. To optimize a safe trajectory for implant positioning, performing transverse imaging to measure the precise insertion corridor angle in the specific vertebra might be considered worthwhile.

The limited number of selected breeds in this study opens the possibility that similar statistically significant differences might be present in additional breeds and vertebrae.

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Conflict of Interest
None declared.

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