Use of routine ventrodorsal radiographic views of the pelvis to assess inclination of the wings of the sacrum in dogs

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Objective—To determine the ratio of ventral-to-dorsal transverse diameters between the wings of the sacrum on ventrodorsal radiographic views of the pelvis in large dogs and to validate the reliability of this morphometric analysis for functional interpretation.

Sample Population—Pelvic specimens from 40 large-breed dogs and radiographs of 113 large-breed dogs.

Procedure—In an anatomic and radiographic evaluation, the transverse dorsal diameter (TVDS) and transverse ventral diameter (TVV) between the wings of the sacrum were evaluated in sacrum specimens and on corresponding radiographs of the pelvis and sacrum. The ratio between TVV and TVDS (VD ratio) was calculated. Intraobserver reliability was determined by calculation of the coefficient of variation. In a retrospective radiographic evaluation, the VD ratio was determined in Rottweilers, Golden Retrievers, and German Shepherd Dogs. Correlations between VD ratio and breed, age, and sex were tested.

Results—The VD ratio was significantly higher in Rottweilers than in Golden Retrievers and German Shepherd Dogs, denoting an oblique alignment of the sacral wings in Rottweilers (ie, the dorsal aspects of the sacral wings were located more medially than the ventral aspects) and an almost sagittal alignment in the other breeds. The VD ratio was significantly associated with age but not with sex.

Conclusions and Clinical Relevance—Sagittal alignment of the wings of the sacrum is considered to be biomechanically less efficient. These results provide a basis for further studies to evaluate radiographic assessment of the sacroiliac joints similar to the evaluation for hip dysplasia. (*Am J Vet Res* 2002; 63:1220–1225)

Sacroiliac joints are formed by the tight synchondrosis connecting the sacral and iliac tuberosity and the synovial joint between auricular surfaces of the sacrum and ilium.[1] Its function is to bear weight and transmit propulsion from the pelvic limbs to the vertebral column during locomotion.[2] Mechanical properties of the sacroiliac joints and loading capacity are considerably affected by the alignment of the wings of the sacrum. Alignment of the sacroiliac contact area that is almost horizontal, such as is found in horses,[3,4] allows excellent transmission of biomechanical forces but is consistent with low joint flexibility. Because of an almost sagittal alignment of the wings of the sacrum, the sacroiliac joints in dogs are less rigid; thus, they are more vulnerable to loading forces.[5] The change in alignment of the sacroiliac contact area from almost horizontal to almost sagittal implies that the contribution of the auricular surfaces to weight bearing is reduced, and loading forces have a greater effect on the sacroiliac ligaments. In the case of strictly sagittal alignment, forces will be absorbed primarily or exclusively by the sacroiliac ligaments.[5] In a postmortem study,[5] it was found that the sagittal inclination angle of the wings of the sacrum is significantly lower and, therefore, biomechanically less efficient in large-breed dogs than in small-breed dogs. In that study, lowest inclination angle (almost sagittal alignment) of the sacral wings was evident in German Shepherd Dogs.

Other studies[6-8] that have been based on biomechanics of the hip joints indicate that in a 4-legged stance, approximately 30 to 40% of body weight is distributed to the pelvic limbs. However, during locomotion, the hip joints are subjected to forces of approximately 3 times body weight.[8] Because weight bearing is transmitted through the coxofemoral joint, acetabulum, and ilium to the sacrum and lumbar vertebrae, the load on the sacroiliac joints is suspected to be similarly high.[2] Above all, the load on the sacroiliac joints in dogs is considerably affected by the high variability of body conformation, body weight, and activity.[2]

Conditions of the adjoining coxofemoral joints and lumbosacral junction, such as hip dysplasia and lumbosacral stenosis, are commonly diagnosed in large dogs.[2,6,8-19] However, despite its central topographic and functional position, the sacroiliac joints have seldom been the topic of radiographic investigations. In contrast, degenerative diseases of the sacroiliac joints, which have to be clearly separated from intra-articular bony ankylosis in patients with inflammatory or rheumatoid diseases (Morbus Bechterew),[20-22] have been identified as factors causing low back pain in humans.[21,23,24] Proposed etiologic factors include overloading, hormonal relaxation of the sacroiliac ligaments, and trauma.[21-24] Even microtrauma from daily repetitive activities is sufficient to cause injury to the sacroiliac joints.[21]

The purpose of the study reported here was to provide an objective method for radiographic scoring of the degree of sagittal inclination of the wings of the sacrum in dogs that would be applicable in clinical assessments. This method should provide a basis for further prospective clinical studies to clarify the importance of differences in inclination of the wings of the sacrum on injuries of the sacroiliac joint.

Received Jan 21, 2002.
Accepted May 16, 2002.
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Materials and Methods

Anatomic and radiographic evaluation—Appropriate measuring points were determined by use of a sample of 40 cadavers of large dogs obtained from the Department of Pathology and Forensic Veterinary Medicine of the University of Veterinary Medicine, Vienna. This population included 4 Bernese Mountain Dogs, 6 Doberman Pinschers, 11 German Shepherd Dogs, 4 Golden Retrievers, 4 Large Munsterlanders, 8 Rottweilers, and 3 Collies. Dogs were 0.5 to 12.0 years old.

Dogs were euthanatized, and the pelvic region was radiographed in symmetric ventrodorsal views. After radiography, the pelvic bones of each cadaver were dissected. Depending on the degree of hyperextension of the lumbosacral junction, ventrodorsal radiographs were obtained by use of 2 techniques. For the first technique, the hind limbs were extended slightly caudally, and the sacrum was aligned almost parallel to the radiographic film (sacrum projected in a central view; **Fig 1**). For the second technique, the hind limbs were extended fully caudally, and the sacrum was maximally inclined in relation to the radiographic film (sacrum projected in an angled view). To assist in radiographic interpretation, corresponding ventrodorsal radiographs were obtained by use of the dissected specimens of the combined pelvis and sacrum and by use of the isolated sacrum for central and angled views, respectively. Wedges were used to aid in positioning of the specimens for angled views. All radiographs were obtained with the x-ray beam centered at the middle of the sacrum.

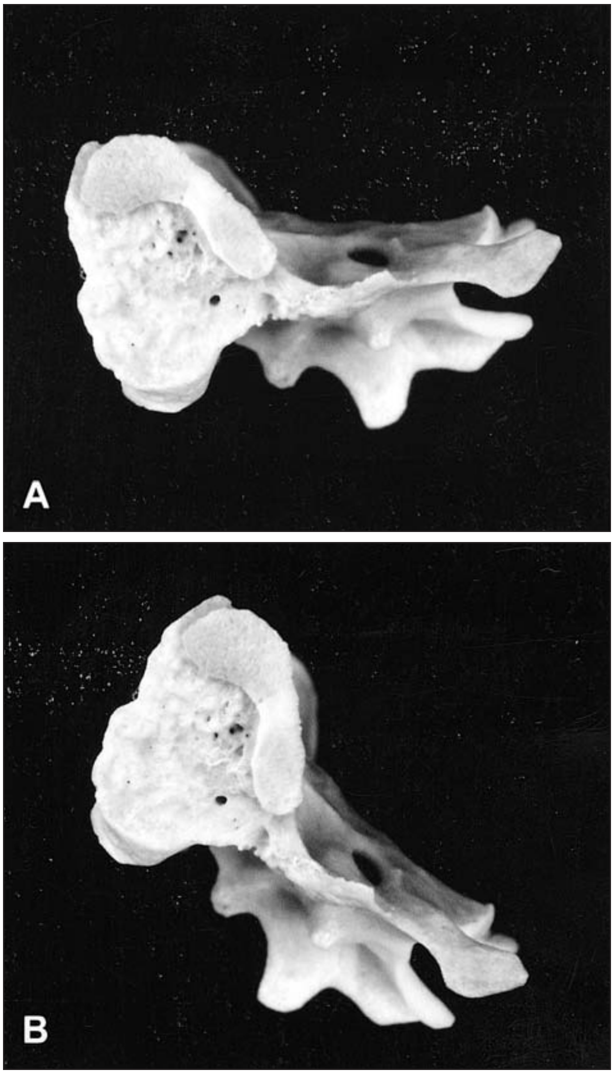

Figure 1—Lateral view of the sacrum of a dog illustrating the effect of positioning on the sacral view obtained in ventrodorsal radiographs. The sacrum may be depicted in a central view (A) or, in the case of maximal hyperextension of the lumbosacral junction, an angled view (B).

Retrospective radiographic evaluation—A total of 1,093 ventrodorsal radiographs of the pelvis and hip joints of dogs were obtained for review.[a] For the routine position, the dogs had been positioned in dorsal recumbency with the pelvis centered symmetrically. Both hind limbs had been fully extended directly caudally so that the femurs were parallel. The stifles had been rotated internally so that the patella was centrally positioned on the midline of each limb.[9,25]

Radiographic examination of the pelvis was conducted for 2 groups of dogs. Group 1 included dogs that had been evaluated for hip dysplasia; these dogs had been anesthetized during radiographic examination. Group 2 included dogs that had been evaluated for various other indications; these dogs had been conscious during radiographic examination. Rottweilers, Golden Retrievers, and German Shepherd Dogs were identified as the 3 breeds of dog most highly represented. A random sample of 25 radiographs was obtained for each group for each of those 3 breeds; thus, there were 150 radiographs used for the investigation (25 radiographs/group × 2 groups × 3 breeds). From this pool of 150 radiographs, we excluded some on the basis of slight asymmetric positioning, feces superimposed on the sacroiliac joints, incomplete pro-

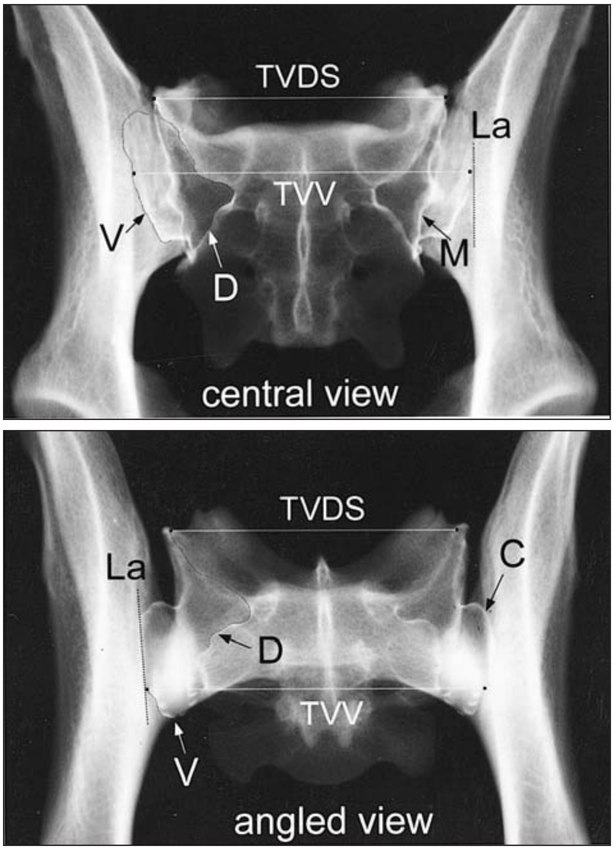

Figure 2—Measuring points to determine the transverse dorsal diameter (TVDS) and transverse ventral diameter (TVV) between the wings of the sacrum relative to the radiographic projections for the central view (top) and angled view (bottom). In this figure, the dorsal (D), ventral (V), middle (M), and cranial (C) contours of the wings of the sacrum were labeled with a 1:1 mixture of barium sulfate and latex to delineate structures. La = Linea arcuata of the ilium.

jection of the sacroiliac joints, transitional vertebrae, and immature joints of dogs < 5 months of age. Dogs were judged to have been symmetrically positioned when there was symmetric projection of the obturator foramen, wings of the ilium, and the hip joints as well as midline projection of the spinous processes. In 7 radiographs, morphometry was not conducted because of imperfect delineation of the measuring points (low quality of the radiographs or complete calcification of the sacroiliac ligaments). We determined that 113 pelvic radiographs obtained from dogs between 0.4 and 12.4 years of age were technically satisfactory for interpretation.

Ventrodorsal inclination of the wings of the sacrum— Mediolateral deviation from the sagittal plane with respect to the ventral aspect of the wings of the sacrum was determined by evaluation of the **transverse dorsal diameter (TVDS)** and **transverse ventral diameter (TVV)** between the wings of the sacrum. The **ratio between TVV and TVDS (VD ratio)** was calculated. The TVDS was determined at the cranial limit of the dorsal margin of the wings of the sacrum whenever the sacrum projected in a central view **(Fig 2)**. The transition between dorsal and cranial margin of the sacral wings was used as a landmark whenever the sacrum projected in an angled view. Measuring points used for determination of TVV were the ventral margins of the wings of the sacrum intersecting the lineae arcuatae of the wing of the ilium for the central and angled views. In central views, the ventral margin of the wings of the sacrum forms an almost straight line, which courses medially at its cranial limit. Identification of measuring points may be assisted by determination of this medial deviation of the ventral margin.

Intraobserver reliability—Intraobserver reliability for determination of TVDS and TVV was tested by use of 20 randomly selected bone specimens and their corresponding radiographs that were from the anatomic and radiographic evaluation. Measurements of bone specimens were performed twice, and measurements of radiographs of the bone specimens (united pelvis and sacrum) were performed 4 times (measurements 1 to 4). To determine the degree of increase attributable to experience in radiographic examination of the sacroiliac joints during this study, we compared the **coefficient of variation (CV)** determined by analyzing the first pair of measurements (measurements 1 and 2) with the CV for the second pair of measurements (measurements 3 and 4) obtained from the radiographs. The effect of method (bone specimen vs radiograph) and radiographic projection (central vs angled view) was also tested by calculation of the CV. A fixed **film-to-focus distance (FFD)** of 100 cm was used, and the **specimen-to-film distance (SFD)** was determined separately for the dorsal and ventral margins of the wings of the sacrum. Values obtained from radiographs were corrected to account for effects of magnification by use of the following formula[26]: radiographic magnification correction factor = (FFD – SFD)/FFD.

In the retrospective radiographic evaluation, a single investigator (IMK) interpreted each radiograph. All measurements were conducted with calipers and evaluated to an accuracy of 0.01 mm. Differences in magnification between TVDS and TVV expected in central views (SFD of the TVV differs by approx 3.5 cm relative to the SFD of the TVDS determined for bone specimens) and angled views (SFD of the dorsal and ventral margins differ by < 1 cm) were neglected.

Statistical analysis—Statistical analyses of data were performed by use of a statistical software program.[b] Values were tested for a normal distribution (Kolmogorov-Smirnov test), and a 1-way ANOVA (Scheffé test; significance defined at $P < 0.05$) was used to determine significant differences among breeds.

Because of the results of a postmortem study[5] in which investigators detected an association between age and inclination of the sacral wings, regression analysis (quadratic model after logarithmic transformation of age) was performed to determine the effect of age on TVDS, TVV, and the VD ratio. Goodness-of-fit was denoted by values of R^2, and a value of $P < 0.05$ again was the criterion used to define significance. Within breeds, Student *t* tests (significance defined at $P < 0.05$) were used to determine whether there were differences in TVDS, TVV, and the VD ratio between males and females and between 2 selected age groups of dogs (ie, juveniles [< 1 year old] and adults [≥ 1 year old]).

Results

Intraobserver reliability—Intraobserver reliability was determined for 20 specimens. The highest CV

Table 1—Intraobserver reliability determined for transverse dorsal diameter (TVDS), transverse ventral diameter (TVV), and ratio between TVV and TVDS (VD ratio) between the wings of the sacrum for bone specimens and radiographs of bone specimens and radiographic projections

Specimen	Variable	Radiographic view	CV (%)
Bone specimens (first and second measurements)			
	TVDS	NA	0.9
	TVV	NA	1.2
	VD ratio	NA	1.3
Radiograph of bone specimens			
First and second measurements	TVDS	Central	2.6
Third and fourth measurements	TVDS	Central	2.0
First and second measurements	TVV	Central	2.2
Third and fourth measurements	TVV	Central	2.2
First and second measurements	TVDS	Angled	1.9
Third and fourth measurements	TVDS	Angled	1.1
First and second measurements	TVV	Angled	2.9
Third and fourth measurements	TVV	Angled	2.5
Second and fourth measurements	VD ratio	Central	2.5
Second and fourth measurements	VD ratio	Angled	2.9
Fourth measurement	VD ratio	Angled vs Central	2.8
Bone specimens and radiograph of bone specimens*			
	VD ratio	Central	2.5
	VD ratio	Angled	2.9

*Second measurement of bone specimens and fourth measurement of radiograph of the bone specimens. NA = Not applicable. CV = Coefficient of variation.

Table 2—Number of dogs on the basis of breed, sex, and age whose radiographs were included in a retrospective radiographic evaluation of diameters between the wings of the sacrum

	Juveniles (< 1 year old)			Adults (≥ 1 year old)			
	Sex		Mean	Sex		Mean ± SD	
Breed	M	F	age (y)	M	F	age (y)	Total
Rottweiler	6	3	0.70	21	16	2.32 ± 2.26[a]	**46**
Golden Retriever	2	0	0.50	20	15	2.40 ± 1.43[a]	**37**
German Shepherd Dog	1	2	0.80	19	8	4.67 ± 3.46[b]	**30**
Total	**9**	**5**	**0.69**	**60**	**39**	**2.99 ± 2.60**	**113**

[a,b]Values with different superscript letters differ significantly ($P < 0.05$).

detected was 2.9% (**Table 1**). On the basis of this analysis, differences of > 2.9% among breeds for the VD ratio were considered to be greater than the value attributable to variability in measurements.

Effect of age—The potential effect of age on TVDS and TVV was tested by use of values for Rottweilers, because the influence of breed was unknown and the highest number of juvenile dogs was of this breed (**Table 2**). Both TVV and TVDS increased significantly ($P < 0.001$) with age (R^2 for TVV, 0.5081; R^2 for TVDS, 0.2419; **Fig 3**).

Although the equation describing the association between age and transverse diameters denoted an increase in size up to the age of 3.5 and 4.4 years for TVV and TVDS, respectively, this increase was most evident in juvenile dogs and only marginal in dogs > 1 year old (Fig 3). For the following analyses, dogs ≥ 1 year old were grouped as adults, because their values were within the same range. The VD ratio of juvenile Rottweilers (mean ± SD, 1.0830 ± 0.0654; minimum, 0.9900; maximum, 1.1621) was significantly ($P < 0.001$) lower than the VD ratio of adult Rottweilers (**Table 3**). Corresponding calculations could not be conducted for juvenile Golden Retrievers and German Shepherd Dogs because of the low number of dogs for each of those breeds.

VD ratio in adult dogs—Mean age of adult (≥ 1 year old) dogs differed significantly among breeds; German Shepherd Dogs were significantly older than Rottweilers or Golden Retrievers (Table 2). Adult (≥ 1 year old) Rottweilers had a significantly higher VD ratio (Table 3), compared with the ratio for Golden Retrievers or German Shepherd Dogs. This denoted an oblique alignment of the sacroiliac joints in Rottweilers and a sagittal alignment in the other 2 breeds. Mean VD ratio in Golden Retrievers and German Shepherd Dogs was 4.1 and 5.6%, respectively, which was lower than that in Rottweilers. Mean difference in VD ratio between Golden Retrievers and German Shepherd Dogs was 1.5%. The highest number of dogs with sagittal alignment of the wings of the sacrum was in German Shepherd Dogs, whereas the highest number of dogs with oblique alignment of the wings of the sacrum was in Rottweilers (**Fig 4**).

Although German Shepherd Dogs were significantly older than the other breeds of dogs, this did not affect results. We did not detect a significant association between age and VD ratio in adult German Shepherd Dogs (R^2, 0.092; $P = 0.328$). Values for TVV and TVDS increased up to the age of 4.4 years; therefore, an additional test was performed that only included dogs between 1 and 4.4 years of age (Table 3). In this sample, dogs were not significantly different in age (mean ± SD; Rottweilers, 1.69 ± 0.98 years; Golden Retrievers, 1.93 ± 0.80 years; German Shepherd Dogs, 1.83 ± 0.60

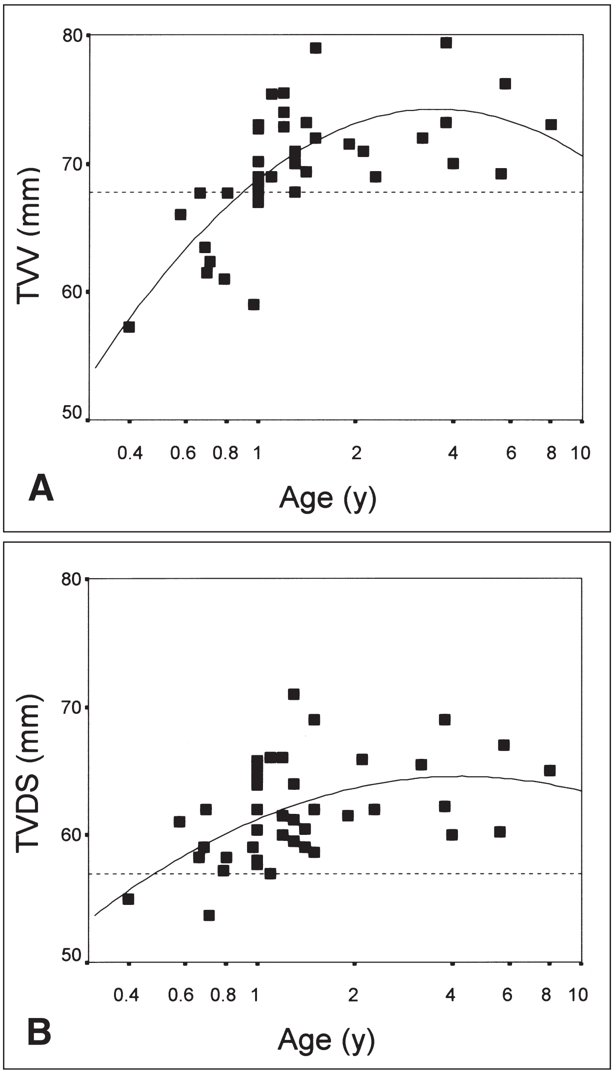

Figure 3—Association between age and the dimension of the TVV (A) and TVDS (B) between the wings of the sacrum in Rottweilers. Each symbol represents values for 1 dog. The line of best fit for the data (solid line) was determined by use of regression analysis. The lowest value observed in adult dogs (dotted horizontal line) was 67.8 mm for TVV and 57.0 mm for TVDS. Equation for the line of best fit was as follows: $TVV = 68.81 + 20.24x - 18.51x^2$ and $TVDS = 61.16 + 10.25x - 7.98x^2$; where x is the logarithmically transformed value for age.

Table 3—Comparison of VD ratio in adult Rottweilers, Golden Retrievers, and German Shepherd Dogs and in a selected group of adult dogs

Breed	Mean ± SD	Minimum	Maximum
All adult dogs ≥ 1 year old (n = 99)			
Rottweiler (37)	1.1346 ± 0.063[a]	1.0000	1.2701
Golden Retriever (35)	1.0895 ± 0.065[b]	0.9665	1.2362
German Shepherd Dog (27)	1.0749 ± 0.059[b]	0.9774	1.1639
Adult dogs between 1 and 4.4 years old (n = 74)			
Rottweiler (30)	1.1422 ± 0.065[a]	1.0000	1.2701
Golden Retriever (30)	1.0944 ± 0.067[b]	0.9665	1.2362
German Shepherd Dog (14)	1.0864 ± 0.056[b]	0.9774	1.1639

See Table 2 for remainder of key.

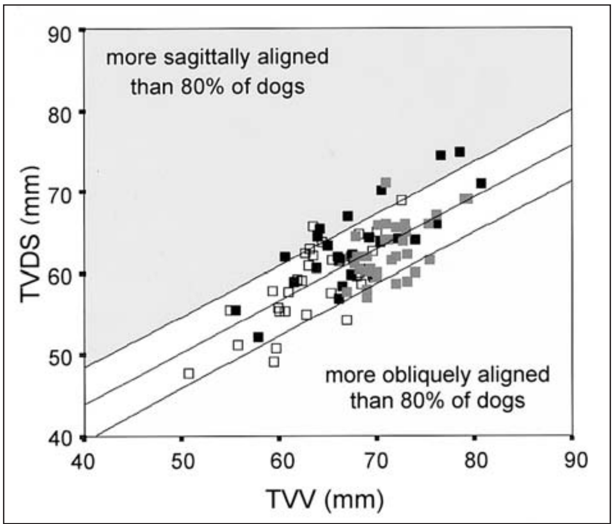

Figure 4—Comparison of TVDS and TVV between the wings of the sacrum in adult large-breed dogs. Each symbol represents values for 1 dog (German Shepherd Dog [black square], Rottweiler [gray square], and Golden Retriever [open square]). The middle line represents the line of best fit for the data, and the other lines represent the upper and lower limits of the 80% confidence interval for the values.

years). This analysis confirmed that the increase in TVDS and TVV was marginal in dogs > 1 year old.

Effect of sex—Dimensions for TVDS and TVV and values for the VD ratio were not significantly affected by sex.

Discussion

Results of the study reported here with regard to reproducibility in radiographic morphometry (ie, CV) are similar to those in humans in which the CV for vertebral body height or calculated height ratio ranged between 0.4 and 4.5%.[27-29] Generally, precision is regarded as good when the CV is < 5%.[29]

Total measurement error of radiographic variables stems from several factors, which include noticeably poor definition of anatomic measuring points, changes in patient position, and inter- and intraobserver variation.[29] Standardized positioning is important, and even small amounts of axial rotation to the left or right should be avoided for radiographic examination of the sacroiliac joints. Studies[29,30] of radiographic intervertebral disc morphometry denote that changes in position (eg, axial rotation), combined with the bias introduced by multiple observers, may produce error amounting to 35 to 50%. However, in the study reported here, transverse diameters of the sacrum did not differ significantly between central and angled views of the sacrum (different views were based on rotation of the sacrum around a transverse axis). Therefore, morphometry of the transverse diameters between the wings of the sacrum provides an objective quantitative assessment of the inclination of the wings of the sacrum and may be used to detect some biomechanically less effective formations that are overlooked by qualitative evaluations. Ventrodorsal radiographic views of the pelvis are recommended, because additional information about the hip joints, proximal portion of the femurs, and lumbosacral junction is available without additional radiation exposure and expense related to obtaining radiographs specifically of the sacroiliac joints.

Results reported here revealed that Rottweilers were more likely to have obliquely aligned wings of the sacrum, whereas German Shepherd Dogs and Golden Retrievers were more likely to have sagittally aligned wings of the sacrum. However, for the interpretation of these findings and for prediction of potential functional consequences, it is important to consider the VD ratio as well as the use and body conformation of each dog. The final dimension of loading forces acting on the hips and sacroiliac joints depends on body weight and activity of each particular dog.[4,8,15,17,19]

The sagittally aligned wings of the ilium and sacrum are firmly united by fibrocartilage and sacroiliac ligaments.[1] Functionally, fibrous fascicles prevent the sacrum from excessive ventral slippage.[31] When loading forces exceed the elastic limits of the supporting soft tissues, the resultant disparity between soft-tissue strength and biomechanical forces will potentiate joint laxity, which will be manifested in a loss of stability and ventral slippage of the sacrum.[31] The efficiency of ligaments, however, depends on the 3-dimensional inclination of the wings of the sacrum to determine the potential direction of motion.[5] The sagittal inclination angle of the wings of the sacrum is directly associated with the craniocaudal inclination angle.[5] Low VD ratios (sagittal alignment of the sacral wings) increase the potential for dorsoventral translational motion, whereas low craniocaudal inclination angles increase the potential for craniocaudal translational motion. Abnormal joint motion, however, implies a modification of force vectors and an increase in pressure placed on the hyaline cartilage leading to metaplasia of hyaline cartilage to fibrocartilage. The final result may be ankylosis or synostosis of the sacroiliac joints.[31] Above all, in cases of strictly vertical alignment of the wings of the sacrum, the ventral aspects of the wings do not bear weight, and forces will be absorbed primarily or exclusively by the sacroiliac ligaments. This may explain why the onset of degenerative joint disease is evident at the ventrolateral border of the sacrum and the dorsomedial aspect of the ilium[31] and also provides evidence for the importance of bony support of the sacroiliac joints by the ventral aspect of the wings of the sacrum,[5] even if it is marginally proportionate.

The overrepresentation of German Shepherd Dogs with sagittally aligned wings of the sacrum (Fig 4), which also was reported in a postmortem study,[5] may indicate a tendency toward weakness of the sacroiliac joints in this breed. These results are in accordance with those of another study[31] in which it was found that there is alteration of the sacroiliac joints in 100% of German Shepherd Dogs by the time they are 3 years old. Unfortunately, Golden Retrievers were not included in that study. Proposed etiologic factors include breed-specific characteristics and body constitution of each dog.[31] In German Shepherd Dogs, breed-specific body constitution implies a considerable caudal shift of the center of gravity resulting in higher loading forces acting on the lumbosacral junction[13] and, consequently, the sacroiliac joints. This may highlight the reason that both structures are frequently affected by degenerative alterations in German Shepherd Dogs.[31]

Three-dimensional modeling of the final inclination of the wings of the sacrum happens between 12 weeks and 12 months of age.[5] Results of the study reported here revealed that the ventral aspect of the wings of the sacrum is especially transformed during this period of life. The most important time in the development of a normal joint is when the periarticular soft tissues are immature.[16] Therefore, the skeletal system is most susceptible to physical or metabolic insult during the first 12 months after birth.[14] Excessive loading forces resulting from rapid growth, excessive increase in body weight, and nonrestrictive activity are formative stimuli that affect the development of the immature skeletal system and increase the risk of skeletal malformation.[14,17-19] Radiographic scoring of the inclination of the wings of the sacrum for functional predictions is not recommended in dogs < 1 year old, because remodelling of the sacral wings is not complete. However, the results reported here provide a basis for further prospective studies to investigate radiographic assessment of the sacroiliac joints in adult dogs, similar to the evaluation for hip dysplasia.

[a]Radiographs were kindly provided by Dr. E. Mayrhofer from the Radiology Clinic of the University of Veterinary Medicine, Vienna.
[b]SPSS, version 6.0.1 for Windows, SPSS Inc, Chicago, Ill.

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