The Veterinary Journal 305 (2024) 106132

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Prevalence of osteoarthritis in the shoulder, elbow, hip and stifle joints of dogs older than 8 years

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ARTICLE INFO

Keywords:
Degenerative joint disease
Older dog
Osteoarthritis
Radiography

ABSTRACT

Osteoarthritis is one of the most common diseases in veterinary medicine. There are various causes for joints developing OA, with some of them being well investigated, while others are still a matter of speculation. In this retrospective study we examined the prevalence of OA in the shoulder, elbow, hip and stifle joints in a clinic population of dogs older than 8 years, which were presented mostly due to orthopaedic complaints. Dogs were included in the study if one or more of the aforementioned joints was included in the radiographs. Radiographs were reviewed by three different observers and graded by severity. Prevalence of OA was 39.2%, 57.4%, 35.9% and 36.4% for the shoulder, elbow, hip and stifle, respectively. There was no correlation between higher grades of OA and weight as well as age, but significantly higher prevalence of OA in heavier groups when grouped for weight. Sex and castration status did not affect presence of OA. As most of the examined joints were free of OA, radiographic findings suggestive of OA should not be considered normal in senescent dogs.

Introduction

Osteoarthritis (OA) is a non-infectious, degenerative disease of cartilaginous joints. It is characterized by depletion of hyaline cartilage and formation of osteophytes at the synovial margins and fibrosis of periarticular soft tissue (Innes, 2018; Schulz et al., 2019). OA can occur primarily and is described as idiopathic with ageing and obesity being associated risk factors (Martel-Pelletier et al., 2016). In dogs, OA is most commonly secondary as a result of structural instabilities (e.g., cranial cruciate ligament rupture (CCLR) or malalignment after fracture), abnormal load distribution on the cartilage (e.g., hip dysplasia (HD), elbow dysplasia (ED)) or after other severe diseases of the joint (e.g. septic arthritis) (Johnson et al., 1994; Lappalainen et al., 2013; Martinez, 1997; Martinez and Coronado, 1997; Paster et al., 2009; Smith et al., 2012; Szabo et al., 2007).

Due to its simplicity and vast availability, radiographic examination of joints after clinical and orthopaedic examination is the most common modality for evaluation of OA. For each joint, there are numerous scoring systems, each of them using different anatomical landmarks for assessment. Most of them finally result in four grades: none, mild, moderate and severe (Akerblom and Sjöström, 2007; Lang et al., 1998; Schachner and Lopez, 2015; Wessely et al., 2017).

In both human and veterinary medicine, OA is the most commonly diagnosed joint pathology (Alves et al., 2020; Sharma et al., 2007). Recent studies indicate that 38–40% of dogs were found to have radiographic OA (Enomoto et al., 2024; Wright et al., 2022) and in a study by Meulenbelt et al. (1997), only 13% of the examined persons between 55 and 65 years were free of radiographic visible OA in the hands, hips, knees and spine (Meulenbelt et al., 1997). These two examples show the enormous number of individuals affected by this disease.

A study by Anderson et al. (2018) found that there is an increased odds ratio for male dogs to develop OA compared to females. Neutered animals were also at significantly higher risk of suffering from OA (Anderson et al., 2018). However, in humans, women are up to twice as likely to develop hand, hip or knee OA as men (Sharma et al., 2007).

In dogs, there is data addressing the association between gonadectomy and increased development of predisposing factors for OA, such as CCLR and HD (Slauterbeck et al., 2004; van Hagen et al., 2005).

Although OA is considered a degenerative joint disease, the

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https://doi.org/10.1016/j.tvjl.2024.106132
Accepted 9 May 2024
Available online 16 May 2024

radiographic signs appear to be more generative. On the one hand cartilage is degraded and articular space becomes narrowed, but simultaneous to this process, sclerosis, formation of periarticular osteophytes and nerve and vascular growth are promoted, which then becomes radiographically visible (Enomoto et al., 2019; Farrow, 2003; Tirgari, 1978).

Radiographic features of OA include osteophytosis, enthesophytosis, joint effusion, soft tissue swelling, subchondral sclerosis and/or intra-articular mineralization occurring on specific sites for each joint (Innes, 2018).

The objective of this study was to evaluate the prevalence of OA in dogs older than 8 years. We investigated radiographic signs of OA in the shoulder, elbow, hip and stifle joints in dogs, that presented to our hospital. To the authors' knowledge, there is no study describing the distribution of OA in a population of senescent dogs.

Our hypothesis is that the majority of joints of dogs older than 8 years show radiographic signs of OA.

Material and methods

In this retrospective study, records of dogs that had been presented to the veterinary teaching hospital between 2011 and 2019 were used. All dogs aged 8 years or older at the day of presentation were included if one or more of the following radiographs was available: mediolateral projection of the shoulder joint, mediolateral and craniocaudal projection of the elbow joint, ventrodorsal projection of the pelvis, mediolateral and craniocaudal projection of the stifle joints. If more than one joint was visible on the same radiograph or joints were included in abdominal or thoracic radiographs, all joints were included when diagnostic quality was sufficient. Radiographs were excluded if they were not adequately positioned to allow evaluation of the joint. Joints were also excluded if there was evidence of articular fractures, articular neoplasia or a history of surgical procedures such as surgically treated CCLR, total joint replacement or arthrodesis. If more than one radiograph of the same joint at different times was present, only the most recent was included in the study. Clinical records of all included dogs were reviewed for age, breed, sex, neuter status, weight and reason for presentation (orthopaedic or non-orthopaedic). The radiographs were evaluated in a digital environment using commercial DICOM-viewer software (dicomPACS, Oehm&Rehbein GmbH). Each individual joint was graded by the first author according to the modified Kellgren Lawrence Scoring system. This system grades OA by the presence of osteophyte formation, sclerosis and deformity of bone ends, where grade 0 is the absence of all aforementioned features, grade 1 is mild osteophyte formation, grade 2 is moderate osteophyte formation, mild sclerosis and possible deformity of bone ends, and grade 3 is large osteophytes, severe sclerosis and definite deformity of bone ends. The observers were unaware of patient details such as history, reason for presentation or radiology reports during evaluation. To minimize error in discrimination of healthy and affected joints, joints with grade 0 or grade 1 were revaluated blinded to the previous results by a board-certified specialist in diagnostic imaging and a specialist in orthopaedic surgery and member of The Society for X-ray Diagnosis of Genetically Influenced Skeletal Diseases in Small Animals (Gesellschaft für Röntgendiagnostik genetisch beeinflusster Skeletterkrankungen bei Kleintieren (GRSK)).

Patient records and final grading were stored for each joint separately in an Excel spreadsheet (Excel for Mac, Microsoft). Statistical analysis was performed using commercial statistical software (SPSS, IBM Corp.). Descriptive statistical analysis was used to describe the population. Diagrams were generated using Microsoft Excel for graphical representation of the results.

Results were tested for normality using the Kolmogorov-Smirnov test. The Mann-Whitney-U test was used to compare sex, neuter status and the group with an orthopaedic presenting complaint to the non-orthopaedic group. For statistical analysis of the influence of weight, dogs were grouped into small, medium and large individuals according to their body weight (<15 kg, 15–30 kg and >30 kg, respectively). Those groups were compared using the Kruskal-Wallis test. p-values $\leq$ 0.05 were considered to be significant. The correlation between age and OA grade was calculated using the Kendals tau test.

Results

A total of 1873 dogs of 181 different breeds met the inclusion criteria. Included dogs were 957 males (51.1%), 337 of which were castrated (35.2%), 915 females (48.9%), 483 of which were spayed (52.8%) and one hermaphrodite (<0.1%). The mean age of presented dogs was ten years (±1.97 years), with a range from 8 to 18 years. The mean weight was 25 kg (±13.14 kg), with a range from 1.6 kg to 90 kg.

The presenting complaints in 1343 dogs (71.7%) were of orthopaedic nature (e.g., lameness), in 530 cases (28.3%) the reason for the examination was due to other indications (e.g., soft tissue swelling).

A total of 6296 joints were included, 632 shoulders (10.0%), 1158 elbows (18.4%), 2706 hips (43.0%) and 1800 stifles (28.6%). Of all joints 3756 (59.7%) were free of OA, 1293 (20.5%) were grade 1, 640 (10.2%) were grade 2 and 607 (9.6%) were grade 3. The distribution for individual joints is shown in Table 1.

Radiographs of both the left and right joints at the same level were available in 2779 cases. Of these joints, 1447 (52.1%) were bilaterally free of OA, 454 (16,3%) were affected unilaterally and in 878 (31.6%) of the cases, signs of OA were present bilaterally. The distribution of bilaterally free vs. affected joints is shown in Table 2.

Canine patients in the non-orthopaedic group were significantly less affected by OA (p=0.05) and showed significantly lower grades of OA (p=0.05). The distribution of OA for individual joints is compared between the two groups in Fig. 1.

Male and female dogs showed no significant difference in OA grades (p=0.946). Sexually intact individuals did not appear to be affected significantly more often by OA than neutered dogs (p=0.254). There was no correlation between age and OA grade (r=0.025), as well as between body weight and OA grade (r=0.131) with all joints in total. Correlations of OA grades with age and weight for each individual joint are shown in Table 3. In Fig. 2 the distribution of OA between the grades is shown with the study population grouped according to their weight in small (lower than 15 kg), medium (15 kg to 30 kg) and large dogs (over 30 kg). Heavier groups had significantly more individuals with radiographic OA per grade (p<0.001). The distribution of OA across the ages represented in our study can be seen in Fig. 3. It shows that joints with Grade 0 are evenly distributed between all ages.

The seven most represented breeds of the study population are shown with their distribution of OA in each joint in Table 4. Of 126 examined joints in Dachshunds, 119 (91.3%) were found to be free of OA.

Discussion

The results of this study do not support the anecdotal theory that a

Table 1
Distribution of osteoarthritis (OA) grades for each individual joint (n=6296) in absolute and relative numbers.

	Grade 0	Grade 1	Grade 2	Grade 3	Total
Shoulder	384 (60.8%)	138 (21.8%)	76 (12.0%)	34 (5.4%)	632 (10.0%)
Elbow	493 (42.6%)	280 (24.2%)	195 (16.8%)	190 (16.4%)	1158 (18.4%)
Hip	1734 (64.1%)	494 (18.3%)	197 (7.3%)	281 (10.4%)	2706 (43.0%)
Stifle	1145 (63.6%)	381 (21.2%)	172 (9.6%)	102 (5.7%)	1800 (28.6%)
Total	3756 (59.7%)	1293 (20.5%)	640 (10.2%)	607 (9.6%)	6296 (100%)

Table 2
Comparison between bilaterally affected vs. osteoarthritis (OA) free joint pairs in absolute and relative numbers.

	Free	Affected
Shoulder	114 (48.5%)	71 (30.2%)
Elbow	148 (32.0%)	245 (52.9%)
Hip	751 (58.0%)	363 (28.0%)
Stifle	434 (55.3%)	199 (25.4%)

certain degree of osteoarthritic change is normal in senescent dogs, as most of the examined joints (59.7%) were free of radiographic visible OA. Our results report higher numbers of OA compared to other studies with populations where younger individuals were also included. (Alves et al., 2020; Anderson et al., 2018; Anderson et al., 2020; Smith et al., 2012; Smith et al., 2001). This is greatly influenced by the fact, that in our study the majority of the examined dogs was presented for orthopaedic complaints.

In comparison to the study by Anderson et al. (2018), we used standardized evaluation methods for the radiographs with consistent observers, which makes the data less prone to observer bias (Anderson et al., 2018).

The lack of correlation between body weight and OA grades is likely to be due to the fact that body weight alone does not allow conclusions to be drawn about the presence of obesity. This is enhanced by various breeds of different size in our study. As a result, it is solely possible to conclude that higher body weight has a promotive influence on development of OA. On the other hand, large and giant breeds also have a higher prevalence of developmental diseases, which can later lead to OA (Witsberger et al., 2008). In Fig. 2, where dogs are grouped according to their body weight, it can be seen that the fraction of unaffected individuals is significantly less with increasing weight, whereas each grade of OA is significantly larger in percentage. This is in accordance with the results of multiple previous studies (Anderson et al., 2018; Anderson et al., 2020; Kealy et al., 2000; Runge et al., 2008; Sallander et al., 2006; Smith et al., 2012; Smith et al., 2001; Smith et al., 2006).

In future studies, the body condition score (BCS) should be used to facilitate conclusions about the effects of the dog being overweight instead of body weight alone. This would also eliminate the bias caused by breeds of different sizes. This was already done on a smaller scale by Kealy et al. (2000), where ad libitum feeding led to higher BCS and thus

Table 3
Correlation of osteoarthritis (OA) grades of all joints in total and separate, with age and weight.

	Age	Weight
Shoulder	0.093	0.155
Elbow	0.035	0.136
Hip	0.04	0.166
Stifle	-0.01	0.007
All	0.023	0.131

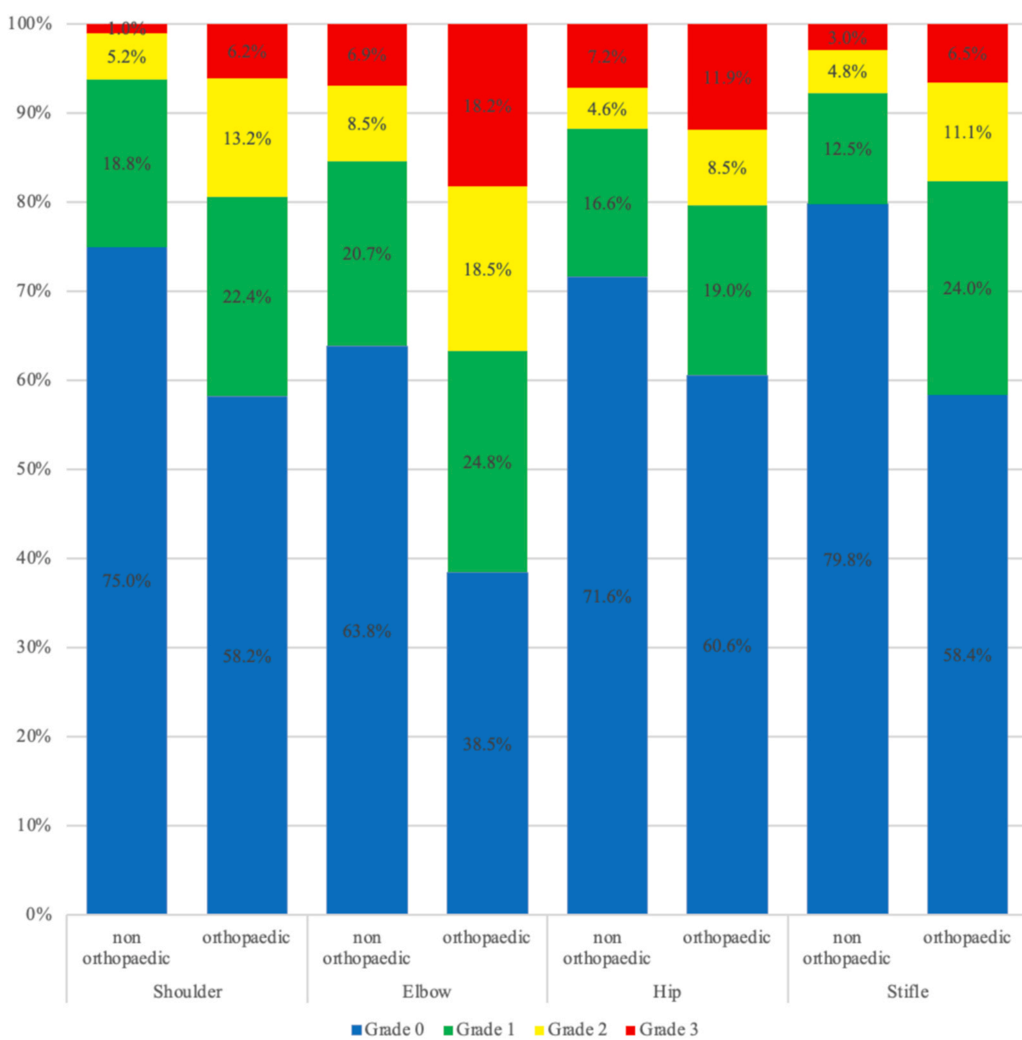

Fig. 1. Distribution of osteoarthritis (OA) grades in each joint, comparison of orthopaedic (n=1343) vs. non-orthopaedic (n=530) presenting complaint.

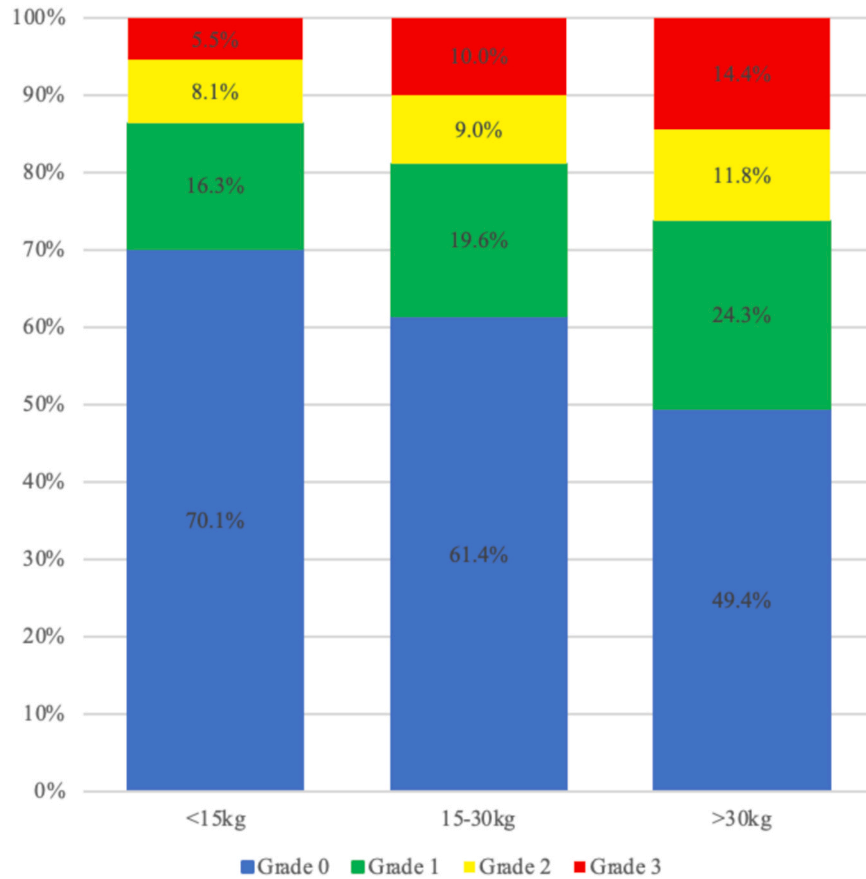

Fig. 2. Distribution of osteoarthritis (OA) grades with dogs grouped for body weight.

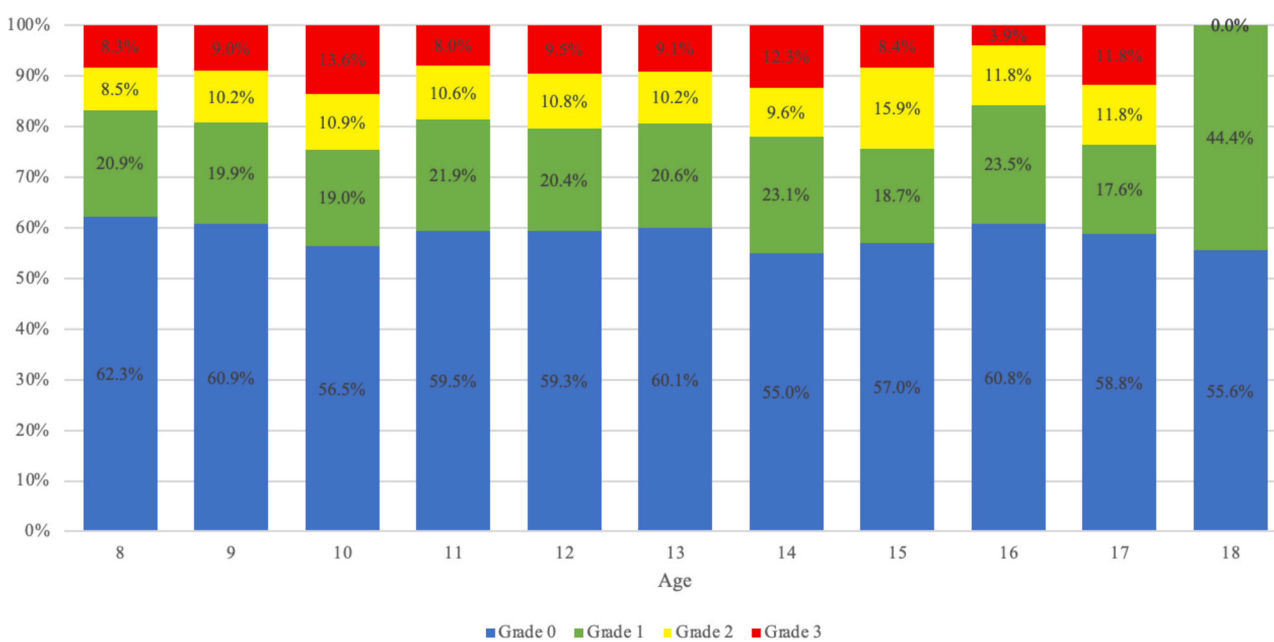

Fig. 3. Distribution of osteoarthritis (OA) grades per year of age.

higher prevalence of OA in Labrador retrievers (Kealy et al., 2000).

In accordance with previous studies, sex and neuter status were not predisposing factors for the presence of signs of OA (Alves et al., 2020; Gilbert et al., 2019; Smith et al., 2001). Conversely, some other previous studies showed that there is a relationship between development of OA and neuter status (Anderson et al., 2018; Anderson et al., 2020). This might be explained by the positive correlation of obesity and neuter status (McGreevy et al., 2005). Additionally, there is a higher incidence of predisposing factors such as CCLR, HD and ED (Lang et al., 1998; Slauterbeck et al., 2004; van Hagen et al., 2005).

Table 4
Distribution of osteoarthritis (OA) grades in each joint, comparison between the seven most common breeds.

Breed	Joint	Grade 0, n (%)	Grade 1, n (%)	Grade 2, n (%)	Grade 3, n (%)	Total, n (%)
Dachshund	Shoulder	11 (64.7)	3 (17.7)	2 (11.8)	1 (5.9)	17 (100)
	Elbow	15 (70.0)	1 (5.3)	3 (15.8)	0 (0)	19 (100)
	Hip	56 (100)	0 (0)	0 (0)	0 (0)	56 (100)
	Stifle	33 (97.1)	1 (2.9)	0 (0)	0 (0)	34 (100)
	Total	115 (91.3)	5 (4.0)	5 (4.0)	1 (0.8)	126 (100)
German shepherd	Shoulder	5 (35.7)	4 (28.6)	1 (7.1)	4 (28.6)	14 (100)
	Elbow	21 (42.9)	12 (24.5)	5 (10.2)	11 (22.5)	49 (100)
	Hip	55 (47.4)	28 (24.1)	12 (10.4)	21 (18.1)	116 (100)
	Stifle	54 (64.3)	16 (19.1)	4 (4.8)	10 (11.9)	84 (100)
	Total	135 (51.3)	60 (22.8)	22 (8.4)	46 (17.5)	263 (100)
Golden retriever	Shoulder	21 (84.0)	4 (16.0)	0 (0)	0 (0)	25 (100)
	Elbow	16 (25.4)	22 (35.0)	7 (11.1)	18 (28.6)	63 (100)
	Hip	50 (49.5)	16 (15.8)	17 (16.8)	18 (17.8)	101 (100)
	Stifle	43 (67.2)	11 (17.2)	9 (14.1)	1 (1.6)	64 (100)
	Total	130 (51.4)	53 (21.0)	33 (13.0)	37 (14.6)	253 (100)
Jack russel terrier	Shoulder	4 (80)	0 (0)	0 (0)	2 (20)	5 (100)
	Elbow	4 (40)	4 (40)	1 (10)	1 (10)	10 (100)
	Hip	65 (82.3)	12 (15.2)	0 (0)	2 (2.5)	79 (100)
	Stifle	36 (58.1)	18 (29.0)	8 (12.9)	0 (0)	62 (100)
	Total	109 (69.9)	34 (21.8)	9 (5.8)	4 (2.6)	156 (100)
Labrador retriever	Shoulder	25 (27.5)	29 (31.9)	26 (28.6)	11 (12.1)	91 (100)
	Elbow	50 (28.1)	37 (20.8)	33 (18.5)	58 (32.6)	178 (100)
	Hip	113 (53.8)	43 (20.5)	17 (8.1)	37 (17.6)	210 (100)
	Stifle	97 (72.4)	21 (15.7)	12 (9.0)	4 (3.0)	134 (100)
	Total	285 (46.5)	130 (21.2)	88 (14.4)	110 (18.0)	613 (100)
Yorkshire terrier	Shoulder	5 (62.5)	3 (37.5)	0 (0)	0 (0)	8 (100)
	Elbow	6 (66.7)	3 (33.3)	0 (0)	0 (0)	9 (100)
	Hip	58 (87.9)	3 (4.5)	2 (3.0)	3 (4.6)	66 (100)
	Stifle	15 (33.3)	19 (42.2)	11 (24.4)	0 (0)	45 (100)
	Total	84 (65.6)	28 (21.9)	13 (10.2)	3 (2.3)	128 (100)
Mixed breed	Shoulder	88 (64.7)	28 (20.6)	16 (11.8)	4 (2.9)	136 (100)
	Elbow	116 (45.3)	69 (27,0)	44 (17.2)	27 (10.6)	256 (100)
	Hip	376 (62.6)	124 (20.6)	35 (5.8)	66 (11.0)	601 (100)
	Stifle	283 (66.3)	80 (18.7)	37 (8.7)	27 (6.3)	427 (100)
	Total	863 (60.8)	301 21.2)	132 (9.3)	124 (8.7)	1420 (100)

Considering that predisposing factors happen at different stages of life and take variable amounts of time to result in radiographically visible OA, we chose 8 years as the lower limit for our study population. Using the example of the stifle joint, most CCLR occur over 3 years of age (Taylor-Brown et al., 2015) and from 7 to 10 years of age (Whitehair et al., 1993) and following OA develops within 13 months (Innes et al., 2004). In contrast, OA from HD that is significantly enough to not breed an individual is radiographically visible by 2 years, though in mild cases, it may not be radiographically visible until later (Smith et al., 2012). Thus, we assume that our study population reflects this development well.

Chung et al. (2023) published a method for relatively assessing radiographic OA by measuring the maximum width and length of an osteophyte and dividing them by the anatomical midline of the according assessment point (Chung et al., 2023). Although time-consuming, this scheme could be adapted to other joints and thus close the gap of measurements in different sized dogs. For the present study, we decided to sacrifice this precision for the quantity we could achieve with plain radiography and grading with the Kellgren-Lawrence system (Kellgren and Lawrence, 1957).

Resulting from this lack of quantitative scoring schemes for every joint, a limitation of the present study is that assessment of OA has an implicit subjective component, as the borders between individual grades might shift. To address our hypothesis, our primary goal was to achieve the most certainty between grade 0 and grade 1, which is why we designed this study with a multi-observer evaluation.

Dividing severity of OA into groups with none, mild, moderate and severe was already used in a human medicine study by Kellgren and Lawrence (1957), with the sole difference being that there was a fifth group between none and mild named “doubtful” (Kellgren and Lawrence, 1957). In later studies, including this one, the grade “doubtful” was omitted and grading OA in the four given groups has been used for decades and can be considered common practice in radiology. However, using four grades does not reflect the gradual biological change of the disease, but is necessary for statistical analysis of data of this nature to evaluate the prevalence of radiographic OA in older dogs.

Digital radiography of joints is not the most sensitive mode of diagnostic imaging for OA detection. Computed tomography provides more detailed information about bony structures which might be missed on plain radiography (Chung et al., 2023; Jones et al., 2022). This inevitably results in underestimation of the prevalence and might also influence the grading. However, spatial resolution of radiography is still superior to computed tomography and the most commonly used modality in the detection of OA (Chung et al., 2023). Given the retrospective nature of our study, we found that the high number of radiographs outweighs the additional detail through CT.

In our study, the prevalence of OA in Dachshunds was extremely low. This could be a true finding, but it should be considered that the shape of bones and joints in chondrodystrophic breeds might mask osteophytosis and therefore complicates radiographic evaluation.

We also found that elbow OA is more likely to cause forelimb lameness and thus have a dog present for radiographs. This finding was even more evident when only cases with bilateral radiographs were considered, with roughly 32% of the examined dogs being free of OA in the elbows. A promoting factor might be the fact that dogs are bearing more weight on the front limbs than on the hind limbs (Budsberg et al., 1987). However, we could not make the same observation in the shoulder joint. Another explanation could be the complexity of the elbow joint involving three articulating bones. As it was already shown with HD, very mild ED in a young age could lead to OA later in life (Andronescu et al., 2015).

Our results suggest a lower correlation of OA with age and weight in the stifle joint compared to all other joints evaluated. One reason could be the relatively large size of the joint surface and the presence of the meniscus distributing the load and therefore minimization of the peak force on the joint surface. Another possible explanation could be the fact that the most frequent predisposing factor for joint instability and thus development of OA in the stifle is a CCLR, which usually occurs later in life and has a fast progression of osteophytosis (Innes et al., 2004; Whitehair et al., 1993). As a result, the presence of CCLR seems to be the most defining factor for OA in the stifle. For further studies, orthopaedic examinations should be included to evaluate the prevalence of radiographic OA in stifles without clinical signs of joint instability.

According to a study by Gordon et al. there is a lack of correlation between severity of radiographic signs for OA and stifle lameness scores in dogs (Gordon et al., 2003). We assume that the same is valid for shoulder, elbow and hip joints, but based on the retrospective nature of this study, we were not able to assess joint pain objectively through orthopaedic examination or owner questionnaires. We cannot tell how often OA was considered to be the cause of the lameness or an incidental finding, but the presence of radiographic OA in the non-orthopaedic group suggests that those individuals did not show any lameness at the time of presentation. Enomoto et al. (2024) found that 40–60% of young dogs with radiographic OA also had clinical OA (Enomoto et al., 2024). In future prospective studies, this is an additional parameter that could be assessed to strengthen the clinical relevance of the study.

The examined population consisting of individuals presenting to a veterinary hospital causes a bias overestimating the prevalence of OA. Also due to the retrospective nature of this study, the majority of the examined dogs had radiographs taken because of orthopaedic presenting complaints, which contributes to this fact. Additionally, we cannot tell how often the contralateral joint was examined for comparative reasons, or because of clinical signs. As a result, the true prevalence of OA is likely even lower than reported in our study, as it is expected that dogs with an orthopaedic presenting complaint had higher rate of OA than dogs presented for a non-orthopaedic reason.

Conclusions

Even though our results are subject to overestimation due to selection bias, most joints in dogs older than eight years are free of OA. Therefore, we suppose radiographic evidence of OA in older dogs should not be considered normal. Future studies need to determine if there is a correlation between radiographic and clinical severity. In our population, the elbow joint seems to be more prone to OA than shoulder, hip and stifle joints.

CRediT authorship contribution statement

Sven Reese: Formal analysis. **Andrea Meyer-Lindenberg:** Writing – review & editing, Supervision, Project administration, Investigation, Conceptualization. **Moritz Roitner:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Julius Klever:** Writing – review & editing, Visualization, Supervision, Investigation, Conceptualization.

Declaration of Competing Interest

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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